

# **AMBIENT PARTICULATE MATTER IN ALBERTA**

Prepared for:

Science and Technology Branch  
Environmental Sciences Division  
Alberta Environmental Protection  
9820 - 106 Street  
Edmonton, Alberta T5K 2J6

by

***Dr. H.S. (Harby) Sandhu***

Atmospheric Science and Management Associates  
2446 - 78 Street  
Edmonton, Alberta T6K 3W4

**September, 1998**

Pub. T/430  
ISBN: 0-7785-0405-0

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Any comments, questions or suggestions regarding the content of this document may be directed to:

Science and Technology Branch  
Environmental Sciences Division  
Alberta Environmental Protection  
4<sup>th</sup> Floor, 9820 - 106 Street  
Edmonton, Alberta T5K 2J6

Telephone: (403) 427-5883

This report may be cited as:

Sandhu, H.S., 1998. Ambient particulate matter in Alberta. Report prepared for Science and Technology Branch, Alberta Environmental Protection, No. 1494-A-9805, Edmonton, Alberta.

## SUMMARY

Ambient inhalable particulate matter concentrations have been associated with a variety of human health effects, including mortality, hospital admissions, respiratory symptoms and illness measured in community surveys, and changes in pulmonary mechanical functions. In Canada, Federal and Provincial governments are in the process of setting national air quality objectives for particulate matter (PM) of sizes 10 and 2.5  $\mu\text{m}$ . Available ambient particulate matter monitoring information from Alberta has been reviewed. Agencies, industry and associations involved in monitoring for particulates have been identified.

Inhalable particulate measurements from 1984 to 1994 at Edmonton and Calgary show similar physical and chemical properties that are comparable to other Canadian prairie cities. However, particulate measurements in these two Alberta cities exhibit characteristics significantly different to those obtained in eastern North American cities. Median  $\text{PM}_{10}$  concentration is about 25  $\mu\text{g m}^{-3}$ , which is approximately 63% of total suspended particulates (TSP), whereas  $\text{PM}_{2.5}$  concentration is about 40% of that of  $\text{PM}_{10}$ . Over the 10 years there was a decreasing trend in both size fractions.  $\text{PM}_{2.5}$  shows a similar seasonal pattern in Edmonton and Calgary, with a slightly higher concentration in winter; whereas coarse particles are generally higher in spring at Edmonton and in winter at Calgary.

Sulphate is the highest explainable mass fraction in fine particles, while minerals contribute most to the coarse particles. About 80% of the total sulphur mass is within the fine particle fraction. Seasonal variations within individual chemical components are relatively less than that among chemical components. Particles of different sizes originate from distinct source sectors. Seasonal variations in source contribution are detected, particularly for mineral soil and road salt. In the ambient concentration data, organic and elemental carbons were not analyzed. Unknown fractions of chemical species in both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  are about 50 and 70 percent, respectively. Additional chemical analysis of this unknown fraction would provide useful information.

Besides natural sources, vehicular traffic and industrial emissions in Alberta contribute to both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ . Regional and rural background particulate matter information from different Alberta regions is limited. Results of preliminary monitoring undertaken outside cities in Alberta indicate a large variation in mean and maximum values. Industry data on total suspended particulates should be analyzed, using correlations developed by Alberta Environmental Protection or from the literature, to estimate  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ . Analyses of exceedances from the proposed 24-hour objective for  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  need to be undertaken using currently available data. This information will serve as useful preliminary input to the Alberta objective setting process for particulate matter. Moreover, additional continuous monitoring of particulates, using strict quality control and quality assurance procedures, need to be undertaken in urban and rural settings to define baseline air quality and develop a management strategy for particulates.



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## **ACKNOWLEDGEMENTS**

Thanks are due to Alberta Environmental Protection staff: Long Fu, George Murphy, Randy Angle, Bob Myrick, Lawrence Cheng, John Torneby, Dennis Stokes, Chow-Seng Liu, Fred Powell, Bill Macdonald and Larry Begoray for providing reports and useful discussions. Also, I thank Karen MacDonald of Environment Canada, Tim Whitford of Weldwood of Canada Limited and Eric Peake of Alberta Research Council for providing information promptly. Thanks are also due to members of the Alberta Multistakeholder Group for PM and Ozone, for their constructive comments. I extend sincere thanks to Ms. Meliza Myrick for her word processing skills to put this report in the final format and thank Ms. Lynn Lockhart for preparing the report for publication. Funding from Alberta Environmental Protection is gratefully acknowledged.



## 1.0 INTRODUCTION

Atmospheric contaminants or air pollutants are released to the environment from both natural and human-made sources. Natural sources include volcanoes, dust storms, forest fires, vegetative decaying processes and evaporation from large bodies of water. Human-made air pollution is caused by burning of fossil fuels in motor vehicles, home furnaces, industrial facilities and thermal power plants. These human activities account for a major share of common pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, hydrocarbons and airborne particulate matter.

During the 1990s, ambient inhalable particulate matter concentrations have been linked to a variety of human health effects, including mortality, hospital admissions, respiratory symptoms and illness measured in community surveys and changes in pulmonary mechanical functions (Burnett et al., 1995; Bates et al., 1990; Dockery et al., 1992; Thurston et al., 1992; Pope et al., 1995; Schwartz et al., 1993; Ostro et al., 1991; Roemer et al., 1993). Although consistency of epidemiological data enhances the confidence of the results, there remains uncertainty regarding the functional forms of the exposure-response relationship; the magnitude and variability of risk estimates; the ability to attribute observed health effects to specific constituents; the time intervals over which health effects are manifested; the extent to which findings in one location can be generalized to other locations; and the nature and magnitude of the overall public health risk imposed by ambient exposure (U.S. Environmental Protection Agency, 1996). Some physical and chemical aspects of atmospheric particulate matter pollution from different locations in Canada have been reported recently (Brook et al., 1997). Also, characteristics of inhalable particulate matter in Alberta cities has been published (Cheng et al., 1998).

Canadian national air quality objectives (maximum acceptable levels) for total suspended particulates are  $120 \mu\text{g m}^{-3}$  for a 24-hour average concentration and  $70 \mu\text{g m}^{-3}$  for an annual mean. The Alberta ambient air quality guidelines for total suspended particulates are 100 and  $60 \mu\text{g m}^{-3}$ , respectively. In July 1997, the U.S. Environmental Protection Agency (U.S. EPA) announced the revised National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) with aerodynamic diameter less than  $10 \mu\text{m}$  ( $\text{PM}_{10}$ ):  $50 \mu\text{g m}^{-3}$  for an annual mean and  $150 \mu\text{g m}^{-3}$  for a 24-hour average (U.S. Environmental Protection Agency, 1997). Two new standards were added by the U.S. E.P.A. for particles less than  $2.5 \mu\text{m}$  ( $\text{PM}_{2.5}$ ): an annual standard for  $15 \mu\text{g m}^{-3}$  and a 24-hour standard of  $65 \mu\text{g m}^{-3}$ .

In Canada, the Federal-Provincial Working Group on Air Quality Objectives and Guidelines, set up under the Canadian Environmental Protection Act (CEPA), has published "A protocol for the development of national ambient air quality objectives. Part I: Science assessment document and derivation of the reference level(s)" (WGAQOG, 1996). This group has also published the following two draft reports:

1. National Ambient Air Quality Objectives for Particulate Matter Less than  $10 \mu\text{m}$  ( $\text{PM}_{10}$ ). Part 1: Science Assessment Document (WGAQOG, 1996).

2. National Ambient Air Quality Objectives for Particulate Matter. Part 2: Recommended Air Quality Objectives (WGAQOG, 1997).

Alberta Environmental Protection is a long standing member and active participant of this Working Group.

In order to assess the ramifications of the recommended national objectives on particulate matter on the provincial data, Alberta Environmental Protection asked Dr. Harby Sandhu of Atmospheric Science and Management Associates to prepare a report.

The terms of reference for this work were as follows:

1. Identify agencies, associations and industry which are collecting data on TSP, PM<sub>10</sub>, and PM<sub>2.5</sub> in Alberta.
2. Compile a list of study reports, published papers and other relevant information from Alberta on PM starting from the year 1990.
3. Provide a literature review on all papers and reports produced for Alberta.
4. Review and assess the information compiled. Relate Alberta information to the national scene whenever possible (compare ambient PM levels in Alberta to the proposed reference levels and Air Quality Objectives for PM).
5. Prepare a draft report including written text, tables, figures and references for review by Alberta Environmental Protection staff.
6. Incorporate comments and submit the final report in both electronic format (WordPerfect and/or Excel) and hard copies.

## **1.1 Report Format**

An integrated air quality management framework approach was followed in preparing this report. Ambient air quality data in general, including data on particulates, is one of the many elements that constitute the air quality management framework. This report has 7 sections: (1) Introduction, (2) Particulate Matter and Framework, (3) Ambient Particulate Monitoring and Results, (4) Physical and Chemical Characteristics, (5) Discussion, (6) References and (7) Appendices. Sections 3 and 6 address terms of reference 1 and 2 whereas sections 4 and 5 address terms of reference 3 and 4, respectively. Submission of this final report takes care of the last two terms. Words 'mean' and 'average' as well as 'maximum' and 'peak' are used interchangeably in the text. 'Median' denotes the 50th percentile of a distribution. Particulate mass units are micrograms per cubic meter of air ( $\mu\text{g m}^{-3}$ ).

## **2.0 PARTICULATE MATTER AND FRAMEWORK**

Excellent scientific and policy reviews on particulate matter have become available recently. The only attempt in this section is to introduce the reader to general concepts.

### **2.1 Overview**

Atmospheric particles originate from a wide variety of sources. Examples are combustion generated particles such as fly ash or diesel soot, those formed in urban haze, salt particles formed from sea spray, fires and soil based particles. Some particles are solid while others are liquid or a mixture of both liquid and solid. Particles contain inorganic ions, elemental carbon, organic compounds and crustal compounds. The organic fraction is especially complex, containing hundreds of compounds. As many different words and terminologies have been used in the particulate literature over the years, Table 1 summarizes terminology relating to atmospheric particles (after Seinfeld, 1986).

Ambient particles are composed of both a primary and a secondary types of particles. Primary particles are emitted into the atmosphere while secondary particles are the result of chemical transformations of primary emissions such as nitrogen oxides, sulphur dioxide, organic compounds and ammonia. The concentration of primary particles depends upon their emission rate, transport and dispersion and removal rate from the atmosphere. Situation with secondary particles is much more complex (U.S. EPA, 1996). As a result, it is considerably more difficult to relate ambient concentrations of secondary particles to sources of precursor emissions than it is to identify the sources of primary particles. Most often, the physical and chemical characteristic of particles are measured separately.

Particle size is one of the most important parameters in determining its characteristics, effects and fate in the atmosphere. Atmospheric deposition rates, residence time and light scattering are strongly dependent on size. Particle size distributions, therefore, have a strong influence on atmospheric visibility, and through their effect on radiative balance on climate. Although atmospheric particles are often not spherical, their diameters are described by an “equivalent” diameter, that of a sphere which would have the same behaviour.

### **2.2 Mass Distribution**

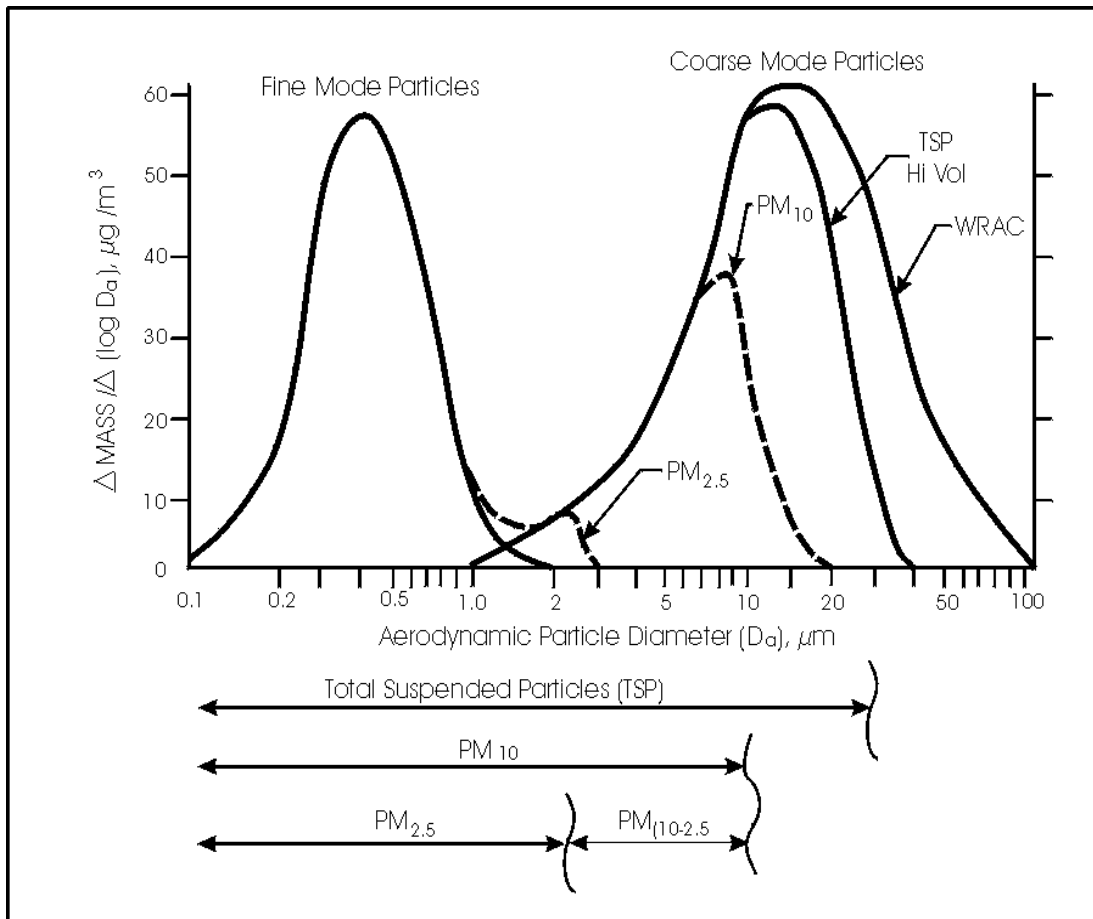
Particulates have the characteristic mass distribution in the ambient air idealized in Figure 1 (U.S. EPA, 1996). For a detailed description of this figure, readers should consult the reference cited. Chemical compositions of coarse and fine particles are distinct. The processes that affect the formation and removal of these two size fractions of atmospheric aerosols are also distinct. Fine and coarse particles are best differentiated by their formation mechanism. Fine particles are formed by nucleation with gases while coarse particles are formed by mechanical processes from large particles. This implies that the two modes have distinct sources. Distinct sources and production mechanisms generate modes of distinct chemical composition. In the coarse mode, crustal (dust, minerals, sea salt) and biological material (pollen, spores, bacteria) are found. By contrast, the fine mode is made

**Table 1 Terminology relating to atmospheric particles (after Seinfeld, 1986).**

<b>Terminology</b>	<b>Definition<sup>1</sup></b>
Aerosols, aerocolloids, aerodisperse systems	Tiny particles dispersed in gases.
Dusts	Suspensions of solid particles produced by mechanical disintegration of material such as crushing, grinding and blasting. $D\rho > 1.0 \mu\text{m}$ .
Fog	A loose term applied to visible aerosols in which the dispersed phase is liquid. Usually, a dispersion of water or ice.
Fume	The solid particles generated by condensation from the vapour state, generally after volatilization from melted substances, and often accompanied by a chemical reaction such as <i>oxidation</i> . Often the material involved is noxious. $D\rho < 1 \mu\text{m}$ .
Hazes	An aerosol that impedes vision and may consist of a combination of water droplets, pollutants and dust. $D\rho < 1 \mu\text{m}$ .
Mists	Liquid, usually water in the form of particles suspended in the atmosphere at or near the surface of the earth; small water droplets floating or falling, approaching the form of rain, and sometimes distinguished from fog as being more transparent or as having particles perceptibly moving downward. $D\rho > 1 \mu\text{m}$ .
Particle	An aerosol particle may consist of a single continuous unit of solid or liquid containing many molecules held together by intermolecular forces and primarily larger than molecular dimensions ( $>0.001 \mu\text{m}$ ). A particle may also be considered to consist of two or more such unit structures held together by interparticle adhesive forces such that it behaves as a single unit in suspension or upon deposit.
Smog	A term derived from smoke and fog, applied to extensive contamination by aerosols. Now sometimes used loosely for any contamination of the air.
Smoke	Small gas-borne particles resulting from incomplete combustion, consisting predominantly of carbon and other combustible material, and present in sufficient quantity to be observable independently of the presence of other solids. $D\rho \geq 0.01 \mu\text{m}$ .
Soot	Agglomerations of particles of carbon impregnated with “tar”, formed in the incomplete combustion of carbonaceous material.

<sup>1</sup> In the list of definitions,  $D\rho$  refers to the equivalent diameter of a spherical particle which has the same settling velocity as the collected particle.





**Figure 1** Idealized ambient mass distribution of particulate matter showing example ranges for Total Suspended Particulate (TSP),  $PM_{10}$  and  $PM_{2.5}$ , as well as coarse PM from  $2.5 \mu\text{m}$  to  $10 \mu\text{m}$  fine PM less than  $2.5 \mu\text{m}$  (U.S. EPA, 1996). WRAC stands for Wide Range Aerosol Classifier.

up of sulphates, nitrates, ammonium, carbon, metals and water; the results of secondary reactions to form particulate matter. The relative proportion of these components will vary with location, season and source characteristics. These different components lead to differing chemical properties. For example, fine particles are typically soluble in water and have higher acidity than the insoluble coarse fraction. Another difference is that fine particles tend to be hygroscopic; that is, the particulate matter will readily absorb water, encouraging growth of the particles, which has implications for visibility and health issues. Because of the ranges of mass and surface area, the two particle modes also differ in atmospheric physical behaviour. Typically, fine particles can remain suspended in the air from days to weeks and can be readily dispersed over a large region. Coarse particles will settle from the air in minutes to hours causing local impacts but not long-range transport. Therefore, when considering options to control particulate matter exposure, fine particle hazes have the potential to be the product of many sources from a wide area making source apportionment very difficult.

### **2.3 Framework**

To place ambient particulate matter information in proper perspective, it is important to understand the existing industrial air quality management system used by the Alberta government (Macdonald and Bietz, 1996). The key components of the system include ambient guidelines, source emission standards, plume dispersion modelling, ambient and source emissions monitoring, environmental reporting, emission inventories, approvals, inspections/abatement, enforcement and research. Linkages among various components are shown in Figure 2. This system was designed to ensure that emissions are minimized through the use of Best Available Demonstrated Technology (BADT) and to ensure that ambient air quality meets Alberta's guidelines. Quantitative relationships between emissions of interest from sources and ambient concentrations are obtained by means of mathematical models that simulate the transport and diffusion of the emitted substances and their chemical transformations. Such models yield both concentrations in the air and deposition levels (Cheng et al., 1995). Current research on source emission profiles and apportionment, funded by Alberta stakeholders, will provide the needed data base to establish such relationships (ARC, 1998).

To meet the present and future challenges on air issues and air quality management, the government of Alberta launched the development of a Clean Air Strategy for Alberta (CASA) through extensive public consultations in 1990 and subsequently endorsed a clean air vision (CASA, 1991; Legge et al., 1992):

“The air will be odourless, tasteless, look clear and have no measurable short- or long-term adverse effects on people, animals or the environment.”

In 1994, Clean Air Strategic Alliance of Alberta (also CASA) was formed and incorporated with representatives from government, industry and non-government organizations. The overarching goal of the Alliance is to develop a new air quality management system for Alberta with specific mandate of: (1) clearly identify the most important air quality issues; (2) prioritize specific problems; (3) allocate and coordinate resources; (4) develop solution oriented action plans; and (5) evaluate

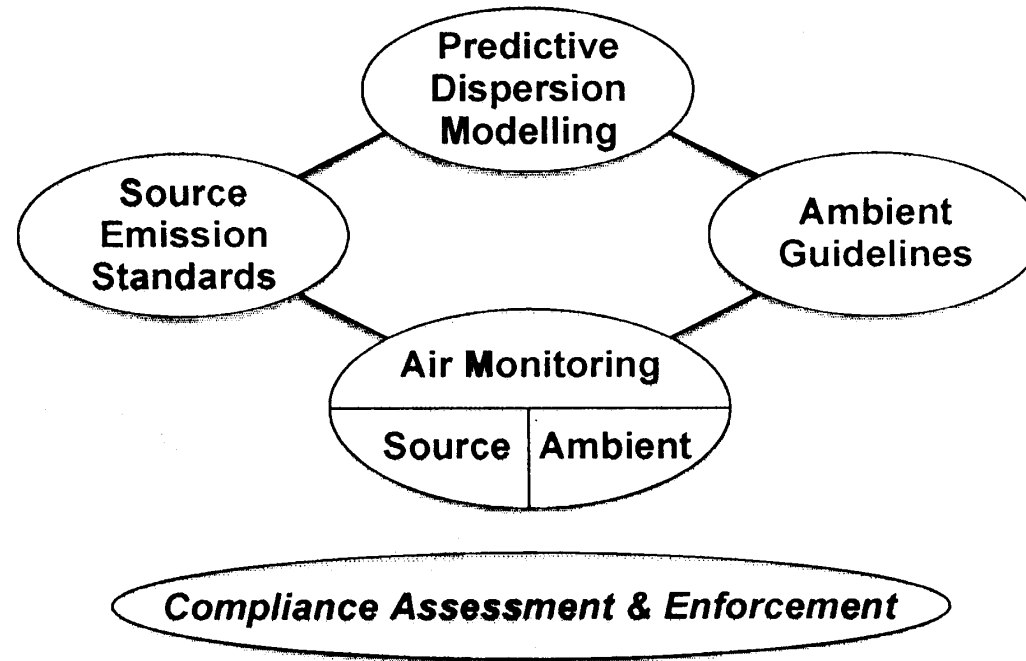
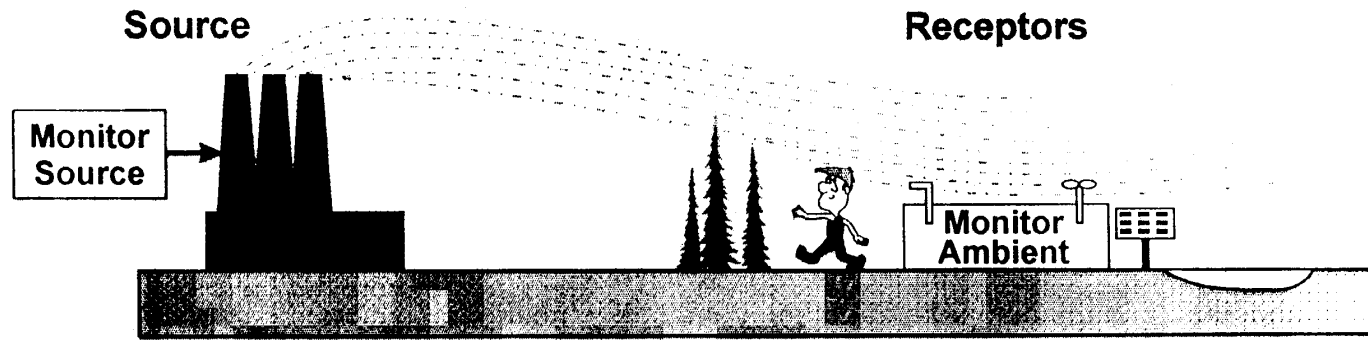


Figure 2 Industrial Air Quality Management System in Alberta (Macdonald and Bietz, 1996).

results. CASA provides an excellent forum for multistakeholder consultations on air issues. The 1996 annual report of the Clean Air Strategic Alliance provides a good overview of the Alliance activities (CASA, 1997). CASA has provided leadership in setting up various zones for air quality management in Alberta, and these are outlined in the 1996 report.

One of the key component in setting an ambient objective for a specific pollutant is the preparation of scientific criteria and assessment documents which outline the dose-response relationships. For the particulate matter the federal-provincial Working Group has already published such documents (WGAQOG, 1996; WGAQOG, 1997). Some of the information from these documents is discussed further in section 5.

## 3.0 AMBIENT PARTICULATE MONITORING AND RESULTS

### 3.1 History of Monitoring Particulates

Recently, Byrne (1996) has summarized the history of particulate monitoring using Chow's (1995) reference. Instead of paraphrasing it again, the following is Byrne's version:

*"Some of the first observations of suspended particulates and health effects can be traced back to the 14<sup>th</sup> century England when correlations were observed among black smoke from chimneys, reduced visibility, black deposits on buildings and clothing, and respiratory distress. Though the measurement method was crude and many of the health effects may have been caused by invisible sulphur dioxide, these observations resulted in a royal decree to reduce the use of coal. This was the first recorded air pollution regulation. In 1910, the first pollution monitoring network was established in London, England and the particle fallout or dustfall collector evolved. This device collected large particles by gravitational settling in enamelled containers. In the 1920s, the British Smoke Shade measurement was developed as a monitoring changes in light reflectance from the darkened spot of the filter paper. In North America, a similar principle was used in the form of Coefficient of Haze (COH), except that it is the measurement of light transmission through the darkened spot on the exposed filter paper. Although light absorption/reflectance monitoring methods were good indicators of particulates that absorb light and were easily adapted to continuous monitoring applications, they are not representative of particles that do not absorb light.*

*The measurement of the mass of particulates was first attempted in 1885 by drawing air through filter paper. This technique was not fully developed until the late 1940s with invention of the mechanized high volume sampler to sample airborne radioactivity after atmospheric testing of nuclear weapons. By the end of the 1970s, several efforts to characterize the high volume sampler had shown that the size selective properties of the units had a  $D_{50}$  (the aerodynamic particle diameter at which 50% of the suspended particles are able to penetrate through the inlet to the filter) ranged from 30  $\mu\text{m}$  to 50  $\mu\text{m}$ . During the 1970s, emerging research on health effects of inhalable particulates motivated the design of size selective inlet (SSI) heads for high volume samplers. Since the invention of the SSI, several other monitors have been developed that can separate particulates into different aerodynamic size categories. Recent advancements in monitoring techniques show a growing emphasis on measurement of finer particulates, performance standards, and continuous based samplers (Chow, 1995)."*

### 3.2 Measurement Techniques

Various methods have been used to measure the particulate matter in the air. Over the years, Alberta measurements have yielded values of either smoke and dust in coefficient of haze (COH) units, total suspended particulates (TSP), particulate matter less than 10  $\mu\text{m}$  ( $\text{PM}_{10}$ ) or  $\text{PM}_{2.5}$ . A tape sampler

is used to measure COH, a high-volume (Hi-Vol) sampler for total suspended particulates, a high-volume sampler with a size selective inlet head (SSI) for daily PM<sub>10</sub> and PM<sub>2.5</sub>. A brief description of these techniques prepared by Byrne (1996) is given in Appendix 1.

Alberta Environmental Protection uses five types of names for their monitoring stations: (1) continuous stations, (2) intermittent stations, (3) static networks, (4) precipitation quality stations, and (5) mobile monitoring. Continuous stations measure hourly concentrations of air contaminants including dust and smoke and inhalable particles while intermittent stations report 24-hour measurements of particulates and other chemicals. Stations that monitor monthly or tri-monthly loadings are called static network. Weekly rain and snow samples are collected at precipitation quality stations. Mobile monitoring is carried out using a Mobile Air Monitoring Laboratory (MAML)--a special vehicle that has been designed to measure the air quality at any locations in Alberta. Detailed description of MAML is available from Alberta Environmental Protection.

### **3.3 Who Is Monitoring?**

Governments, industry and associations are all involved in monitoring of ambient particulate matters. Governments have been monitoring ambient air for the longest time. As part of Environment Canada's National Air Pollution Surveillance (NAPS) network, Alberta Environmental Protection has been routinely monitoring ambient concentrations of particles less than 10 µm in diameter (PM<sub>10</sub>) and particles less than 2.5 µm in diameter (PM<sub>2.5</sub>) using dichotomous samplers at downtown locations in Edmonton and Calgary since 1984 (Dann, 1994). Before that, these agencies have been measuring coefficient of haze and total suspended particulates. Alberta Environmental Protection is also monitoring continuously PM<sub>10</sub> and PM<sub>2.5</sub> in Edmonton Northwest since 1993. Industry is also involved in making measurements on particulates either as a formal or informal requirement by Alberta Environmental Protection. Two associations, Strathcona Industrial Association and West Central Airshed Society, have published reports on air quality monitoring which include particulate information. The Alberta Government-Industry Acid Deposition Research Program (ADRP) also monitored particulate matter (Legge and Krupa, 1990). Locations and facilities for which observations have become available are listed in Tables 2 and 3.

### **3.4 Monitoring Results**

#### ***Governments***

As mentioned earlier, a large body of data on particulates has been collected by Alberta Environmental Protection (AEP) either solely or in cooperation with Environment Canada. All these data have been published in annual reports (AEP, Myrick et al., 1992 to 1998). Three types of annual documents on air quality have been published: (1) Summary Report, (2) Detailed Report and (3) Data Report. To make the reader familiar with the information in these reports, sections on inhalable particles (PM<sub>10</sub>) from the Detailed Report and the total suspended particulates from the Data Report for 1996 are given in Appendix 2. Locations, type of data and the time periods of data collections are already given in Table 2. These locations are shown in Figure 3. Since AEP has collected particulate data using four different techniques, a study was carried out to establish

**Table 2 Particulate monitoring by Alberta Environmental Protection.\***

Location	Parameter (Monitoring Type)	Time Period
Edmonton Central	TSP (intermittent) PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	1980 - present 1984 - present 1984 - present
Edmonton Northwest	TSP (intermittent) PM <sub>10</sub> (intermittent) PM <sub>10</sub> (continuous)	1980 - present 1993 - present 1993 - present
Calgary Central	TSP (intermittent) PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent) PM <sub>10</sub> (continuous) PM <sub>2.5</sub> (continuous)	1980 - present 1984 - present 1984 - present 1995 - present 1997 - present
Calgary Northwest	TSP (intermittent)	1980 - present
Calgary East	TSP (intermittent)	1980 - present
Fort Saskatchewan	TSP (intermittent)	1980 - present
Fort McMurray	PM <sub>2.5</sub> (continuous)	1997 - present
Royal Park (Vegreville)	TSP (intermittent) PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	1993 - present Jan. 1993 - Aug. 1995 Jan. 1993 - Aug. 1995
Beaverlodge	PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	Nov. 1997 - present Nov. 1997 - present
Ellerslie	TSP (intermittent)	1985 - 1991
Drayton Valley	TSP (intermittent) PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	Sept. - Dec. 1989 Sept. - Nov. 1990 Nov. 1989 and Nov. 1990 Nov. 1989 and Nov. 1990
Canmore	PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	Mar. - May 1994
Exshaw	TSP (intermittent)	Jan. - June 1993
Sherwood Park	TSP (mobile) PM <sub>10</sub> (mobile) PM <sub>2.5</sub> (mobile)	Spring, summer and fall of 1997
Caroline/Sundre area	TSP (mobile) PM <sub>10</sub> (mobile) PM <sub>2.5</sub> (mobile)	Spring, summer, fall and winter of 1997/98
Medicine Hat	PM <sub>10</sub> (intermittent)	Feb. - Apr. 1997 Jan. - Mar. 1998
Swan Hills area	TSP (mobile) PM <sub>10</sub> (mobile) PM <sub>2.5</sub> (mobile)	Spring, summer, fall and winter of 1997/98
Gibbons	PM <sub>10</sub> (intermittent) PM <sub>2.5</sub> (intermittent)	Nov. 1997, Mar. 1998

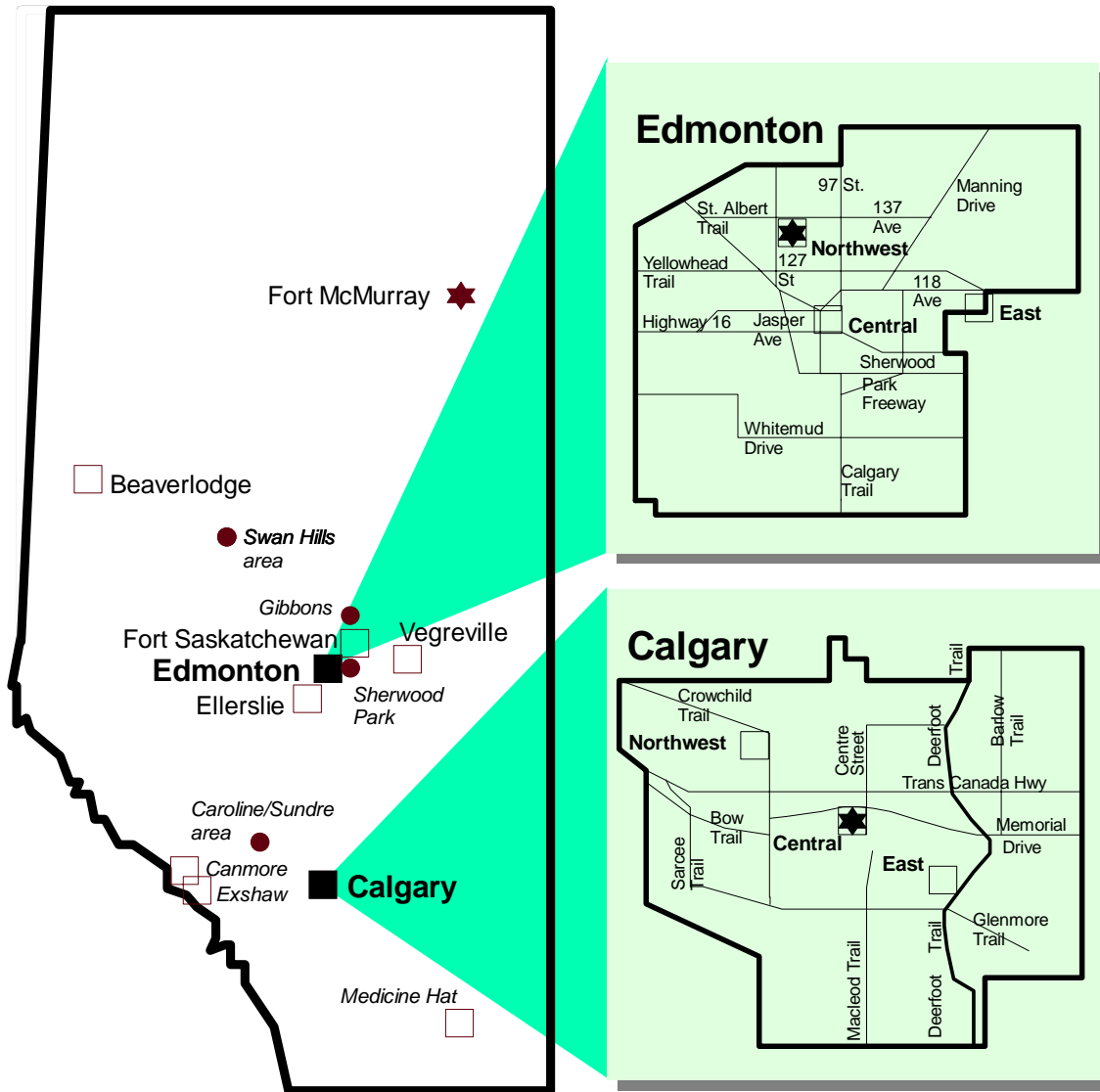
\* Edmonton and Calgary stations have cooperative arrangements with Environment Canada. Also, Environment Canada operates a particulate monitoring project at Esther.

**Table 3 Particulate monitoring by industry and associations.**

<b>Location</b>	<b>Facility</b>	<b>Parameter</b>	<b>Number of Stations</b>
Battle River	Alberta Power Ltd.	TSP	2
Boyle	Alberta-Pacific Forest	TSP	1
Boyle	Millar Western Industries	TSP	1
Caroline	Shell Canada	TSP	1
Coal Valley	Luscar Starco	TSP	2
Drayton Valley	Weyerhaeuser Canada	PM <sub>10</sub>	1
Edson	Weyerhaeuser Canada (OSB Plant)	PM <sub>10</sub>	1
Exshaw	Lafarge Canada Inc.	TSP	2
Fort McMurray	Syncrude Canada	TSP	2
Genessee	Edmonton Power	TSP	2
Grande Cache	Smoky River Coal	TSP	2
Grande Prairie	Can-For Products	TSP, PM <sub>10</sub>	2
Greg River	Greg River	TSP	2
High Level	High Level Forest Products	TSP, PM <sub>10</sub>	2
High Prairie	Buchanan Lumber	TSP	1
High Prairie	Tolko Industries Ltd.	PM <sub>10</sub>	1
H.R. Miller	Alberta Power Ltd.	TSP	1
Innisfail	John Manville Canada	PM <sub>10</sub>	1
Keephills	TransAlta Utilities	TSP	2
Luscar	Cardinal River	TSP	2
Obed	Obed Mountain	TSP	2
Peace River	Daishowa-Marubeni Inc.	PM <sub>10</sub>	1
Slave Lake	Slave Lake Pulp	TSP	1
Sheerness	Alberta Power Ltd.	TSP	2
Sundance	TransAlta Utilities	TSP	4
Wabamun	TransAlta Utilities	TSP	2
Whitecourt	Millar Western Pulp	TSP	1

<b>Location</b>	<b>Association</b>	<b>Parameter</b>	<b>Number of Stations</b>
Edmonton	Strathcona Industrial Association	TSP	3
Drayton Valley	West Central Airshed Society	PM <sub>10</sub> , PM <sub>2.5</sub>	3





- ★ Continuous particulate monitoring location
- Intermittent particulate monitoring location
- Mobile particulate monitoring location

**Figure 3 Alberta Environmental Protection particulate monitoring locations.**

correlations. Symbols in the following correlations are defined in subsection 3.2. Three conclusions were drawn (Byrne, 1996).

Firstly, there is a very weak relationship between COH and  $PM_{10}^{TEOM}$ . For this relationship, the following equation was derived from data collected at the Edmonton Northwest site:

$$PM_{10}^{TEOM} = 31.6[COH] + 13.7$$

The relationship was determined to be weak by the correlation coefficients but it was statistically significant.

Secondly, there is a very strong relationship between  $PM_{10}^{SSI}$  and TSP, with  $PM_{10}^{SSI}$  composing approximately 63% of TSP. The equation developed for the relationship between  $PM_{10}$  and TSP is:

$$PM_{10}^{SSI} = 0.55[TSP] + 2.87$$

Thirdly, there is strong correlation between  $PM_{10}$  measurements made by the TEOM<sup>®</sup> and the SSI. But, the measurements themselves are not equivalent. In fact, SSI measurements of  $PM_{10}$  are consistently higher than those made by the TEOM<sup>®</sup> by 25%. The empirical formula developed that represents the relationship between  $PM_{10}$  from this method and the SSI is:

$$PM_{10}^{TEOM} = 0.785[PM_{10}^{SSI}]$$

It should be noted that these correlations were derived using one site data - Edmonton Northwest. Comparisons with results from other studies suggest that these correlations are location dependent. In spite of this limitation, these correlations have made possible to use earlier smoke and dust as well as TSP data to estimate  $PM_{10}$  concentrations for environmental and human health studies.

Typical sets of data on particulates for Edmonton (urban site) and Royal Park (rural site) for 1993 to 1994 are shown in Tables 4 and 5 and comparison of means and maximum of  $PM_{10}$ ,  $PM_{2.5}$  and  $PM_{2.5-10}$  for three years at Royal Park (1993, 1994, 1995) with Edmonton Central and Calgary Central is shown in Table 6. In consultation with Alberta Environmental Protection staff, the time period 1993 to 1994 was chosen to show a comparison of data in a rural and urban setting because rural site measurements for particulates at Royal Park were terminated in 1995. Particulate nitrate and its formation from precursors in Edmonton and Calgary has been reported before (Peake et al., 1985, 1988).

In response to visibility concerns, the Atmospheric Environment Service of Environment Canada made measurements on visibility using a nephelometer in 1993 and 1994 in Waterton Park. It was reported that regional and Alberta emissions affect visibility; however, Waterton visual range averaged 115 km, while Glacier National Park (U.S.A.) was only 64 km (McDonald et al., 1997). Environment Canada has also made measurements of particulates at Esther.

**Table 4 Typical set of data for Edmonton Central location from October 1993 to October 1994.**

Date	PM <sub>2.5-10</sub> (µg m <sup>-3</sup> )	PM <sub>2.5</sub> (µg m <sup>-3</sup> )	PM <sub>10</sub> (µg m <sup>-3</sup> )	PM <sub>2.5</sub> /PM <sub>10</sub>
10-Oct-93	8.90	11.02	19.92	0.55
16-Oct-93	11.31	8.94	20.25	0.44
22-Oct-93	20.97	11.16	32.13	0.35
28-Oct-93	4.58	4.17	8.75	0.48
03-Nov-93	10.33	4.17	14.50	0.29
09-Nov-93	2.29	7.88	10.17	0.77
15-Nov-93	29.25	8.29	37.54	0.22
21-Nov-93	6.41	2.92	9.33	0.31
27-Nov-93	5.58	6.25	11.83	0.53
03-Dec-93	22.49	10.42	32.92	0.32
09-Dec-93	4.60	9.78	14.38	0.68
15-Dec-93	2.94	9.72	12.67	0.77
02-Jan-94	1.37	10.88	12.25	0.89
08-Jan-94	0.69	6.39	7.08	0.90
14-Jan-94	1.70	5.88	7.58	0.78
20-Jan-94	4.32	11.76	16.08	0.73
26-Jan-94	3.53	20.56	24.08	0.85
01-Feb-94	1.76	3.19	4.96	0.64
07-Feb-94	3.83	15.83	19.67	0.81
13-Feb-94	2.00	2.96	4.96	0.60
19-Feb-94	2.12	3.84	5.96	0.64
25-Feb-94	3.75	22.45	26.21	0.86
03-Mar-94	49.07	6.34	55.42	0.11
09-Mar-94	53.99	15.09	69.08	0.22
15-Mar-94	28.90	6.39	35.29	0.18
21-Mar-94	21.81	10.28	32.08	0.32
27-Mar-94	12.26	3.19	15.46	0.21
02-Apr-94	15.71	5.42	21.13	0.26
08-Apr-94	34.68	14.86	49.54	0.30
14-Apr-94	20.06	3.98	24.04	0.17
26-Apr-94	15.19	4.35	19.54	0.22
02-May-94	38.50	9.95	48.46	0.21
08-May-94	25.36	7.27	32.63	0.22
14-May-94	16.89	3.98	20.88	0.19
20-May-94	2.77	5.23	8.00	0.65
26-May-94	9.10	11.90	21.00	0.57
01-Jun-94	7.47	5.69	13.17	0.43
07-Jun-94	2.68	3.24	5.92	0.55
13-Jun-94	7.08	3.80	10.88	0.35
19-Jun-94	3.81	3.94	7.75	0.51
25-Jun-94	9.44	4.81	14.25	0.34
01-Jul-94	6.92	3.70	10.63	0.35
07-Jul-94	8.46	7.50	15.96	0.47
13-Jul-94	12.69	8.98	21.67	0.41
19-Jul-94	11.14	4.81	15.96	0.30
25-Jul-94	18.06	6.85	24.92	0.27
06-Aug-94	2.59	15.74	18.33	0.86
12-Aug-94	16.47	34.44	50.92	0.68
18-Aug-94	10.57	19.31	29.88	0.65
24-Aug-94	9.94	3.52	13.46	0.26
30-Aug-94	9.25	6.20	15.46	0.40
05-Sep-94	4.44	3.47	7.92	0.44
11-Sep-94	2.16	3.01	5.17	0.58
17-Sep-94	25.69	7.64	33.33	0.23
23-Sep-94	22.04	6.67	28.71	0.23
29-Sep-94	2.99	2.59	5.58	0.46
05-Oct-94	10.06	4.81	14.88	0.32
11-Oct-94	11.04	4.63	15.67	0.30
17-Oct-94	12.91	6.30	19.21	0.33
23-Oct-94	3.31	4.86	8.17	0.60

**Table 5 Typical set of data for Royal Park location from October 1993 to October 1994.**

Date	PM <sub>2.5-10</sub> (µg m <sup>-3</sup> )	PM <sub>2.5</sub> (µg m <sup>-3</sup> )	PM <sub>10</sub> (µg m <sup>-3</sup> )	PM <sub>2.5</sub> /PM <sub>10</sub>
10-Oct-93	11.66	12.50	24.16	0.52
16-Oct-93	7.26	10.65	17.91	0.59
22-Oct-93	19.49	9.26	28.74	0.32
28-Oct-93	4.54	4.63	9.17	0.51
03-Nov-93	3.75	4.17	7.92	0.53
09-Nov-93	1.76	11.57	13.33	0.87
15-Nov-93	2.13	3.70	5.83	0.64
21-Nov-93	2.92	4.17	7.08	0.59
27-Nov-93	6.94	13.89	20.83	0.67
03-Dec-93	2.54	7.87	10.41	0.76
07-Feb-94	6.90	1.85	8.75	0.21
15-Mar-94	3.61	1.39	5.00	0.28
21-Mar-94	2.50	8.34	10.84	0.77
27-Mar-94	0.69	1.39	2.08	0.67
02-Apr-94	7.50	4.17	11.67	0.36
08-Apr-94	10.02	6.75	16.77	0.40
14-Apr-94	9.49	9.27	18.76	0.49
20-Apr-94	4.59	0.00	4.59	0.00
26-Apr-94	11.21	17.14	28.35	0.60
02-May-94	12.41	9.27	21.68	0.43
08-May-94	9.96	8.80	18.76	0.47
14-May-94	17.88	8.80	26.68	0.33
20-May-94	8.20	5.56	13.76	0.40
26-May-94	23.99	10.19	34.18	0.30
01-Jun-94	20.24	6.02	26.26	0.23
07-Jun-94	11.12	5.56	16.67	0.33
13-Jun-94	7.09	8.34	15.42	0.54
19-Jun-94	8.96	6.25	15.21	0.41
01-Jul-94	8.75	8.34	17.09	0.49
06-Jul-94	8.89	31.97	40.85	0.78
12-Jul-94	4.95	8.80	13.76	0.64
18-Jul-94	6.95	9.73	16.67	0.58
24-Jul-94	20.10	11.58	31.68	0.37
30-Jul-94	17.78	13.90	31.68	0.44
05-Aug-94	19.26	40.77	60.03	0.68
11-Aug-94	7.27	10.66	17.93	0.59
17-Aug-94	6.25	25.02	31.27	0.80
23-Aug-94	7.78	5.56	13.34	0.42
29-Aug-94	7.04	8.80	15.84	0.56
04-Sep-94	7.59	7.41	15.01	0.49
10-Sep-94	0.00	0.93	0.93	1.00
16-Sep-94	7.27	2.32	9.59	0.24
22-Sep-94	14.70	2.37	17.07	0.14
28-Sep-94	10.79	4.63	15.42	0.30
05-Oct-94	1.34	3.24	4.59	0.71
11-Oct-94	2.82	5.10	7.92	0.64
17-Oct-94	3.47	6.95	10.42	0.67
23-Oct-94	0.60	2.32	2.92	0.79

**Table 6 Annual particulate mass data at Royal Park, Edmonton Central and Calgary Central stations from 1984 to 1996.**

	<b>PM<sub>2.5-10</sub> (µg m<sup>-3</sup>)</b>		<b>PM<sub>2.5</sub> (µg m<sup>-3</sup>)</b>		<b>PM<sub>10</sub> (µg m<sup>-3</sup>)</b>	
	Mean	Max.	Mean	Max.	Mean	Max.
Royal Park 1993	5.66	21.38	7.87	70.83	13.52	79.57
Royal Park 1994	8.02	23.99	10.22	64.40	18.07	65.03
Royal Park 1995	8.72	31.68	9.64	44.48	18.75	60.86
Royal Park (1993 to 1995)	7.24	31.68	9.14	70.83	16.39	79.57
Edmonton Central (1984 to 1996)	15.79	75.00	10.73	56.25	26.43	86.00
Calgary Central (1984 to 1996)	15.26	84.00	10.82	52.00	25.91	114.00

### ***Industry***

Industrial facilities that monitor particulate matter (Table 3) use the same or equivalent monitoring protocols as developed by Alberta Environmental Protection. A typical set of data report made available from an industry by Alberta Environmental Protection is given in Table 7 (High Level Forest Products, 1997). The authors of this report have recognized the importance of quality control and quality assurance for the reported information because some of their  $PM_{10}/TSP$  ratios were larger than one. Some preliminary observations of Weldwood of Canada-Hinton Division made during 1997 are shown in Table 8.

### ***Associations***

Typical monitoring results from the Strathcona Industrial Association and the West Central Airshed Society are shown in Tables 9 and 10. Though  $PM_{10}$  and  $PM_{2.5}$  data from associations are scarce at the present time, they recognize the importance of making these measurements.

**Table 7 Particulate measurements ( $\mu\text{g m}^{-3}$ ) of High Level Forest Products Ltd. from July to December 1996.**

Month	Day	PM <sub>10</sub>	TSP	PM <sub>10</sub> /TSP
July	3	17	21	0.8
	7	8	8	1.0
	14	4	25	0.2
	17	17	12	1.4
	21	4	13	0.3
	24	4	16	0.3
	28	30	59	0.5
	31	4	12	0.3
August	4	4	4	1.0
	7	4	4	1.0
	11	13	41	0.3
	14	13	21	0.6
	18	17	25	0.7
	21	17	28	0.6
	25	21	4	5.3
	28	13	46	0.3
September	1	12	12	1.0
	4	4	32	0.1
	7	8	M <sup>a</sup>	N/A
	8	12	16	0.8
	11	29	53	0.5
	15	25	4	6.3
	18	33	53	0.6
	22	8	15	0.5
	25	50	27	1.9
29	4	4	1.0	

<sup>a</sup> Missing Data

**Table 7      Continued.**

<b>Month</b>	<b>Day</b>	<b>PM<sub>10</sub></b>	<b>TSP</b>	<b>PM<sub>10</sub>/TSP</b>
October	2	30	83	0.4
	6	27	34	0.8
	9	11	4	2.8
	13	4	4	1.0
	16	4	7	0.6
	20	4	4	1.0
	23	4	4	1.0
	27	4	15	0.3
	30	4	4	1.0
	November	3	7	4
6		4	4	1.0
10		4	77	0.1
13		4	7	0.6
17		3	7	0.4
20		4	10	0.4
24		13	10	1.3
27		15	4	3.8
December	2	7	4	1.8
	4	4	4	1.0
	8	3	8	0.4
	15	5	14	0.4
	22	6	2	3.0
	25	11	M	N/A
	29	7	M	N/A



**Table 8 Preliminary particulate monitoring results ( $\mu\text{g m}^{-3}$ ) of Weldwood of Canada - Hinton Division during 1997.\***

<b>Date</b>	<b>PM<sub>10</sub></b>	<b>PM<sub>2.5</sub></b>
<b>Mountainview Estates - Background</b>		
February 21	10	5
February 8	15	4
March 14	7	6
March 20	4	4
<b>Ambient Station Location</b>		
January 28	21	8
February 8	16	10
February 15	13	9
February 21	18	10
March 8	13	5
March 14	20	8
March 22	18	6
<b>Fenceline - Industrial Park</b>		
February 1	37	14
February 8	20	8
February 15	30	20

\* This was an information baseline study and no strict quality assurance program was instituted.

**Table 9 Summary of total suspended particulates ( $\mu\text{g m}^{-3}$ ) measured by Strathcona Industrial Association during 1996.**

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	STATION MAX.	ANNUAL AVERAGE arith. geom.
<b>SHERWOOD PARK (2)</b>														
First Sample	12.7	31.5	45.2	25.8	15.8	34.8	25.8	55.6	21.0	13.7	21.4	22.1	<b>55.6</b>	
Second Sample	18.9	23.4	33.5	29.8	54.1	39.7	21.0	N.A.	48.7	30.9	6.6	27.1	<b>54.1</b>	
Third Sample	25.3	24.7	41.1*	43.7	10.1	41.2	35.5	32.4	15.8	43.0	5.8	16.1	<b>43.7</b>	
Fourth Sample	20.5	58.5	22.1	20.3	31.6	13.5	22.4	22.6	36.0	36.2	27.9	19.0	<b>58.5</b>	
Fifth Sample	31.6	97.7	37.7	22.7	28.6	21.0	29.3	45.6	7.1	24.0	18.9	11.0	<b>97.7</b>	
Sixth Sample	-	-	-	-	-	-	-	33.8	-	-	-	-	<b>33.8</b>	
<b>MONTHLY AVERAGE</b>	<b>21.8</b>	<b>47.2</b>	<b>35.9</b>	<b>28.5</b>	<b>28.0</b>	<b>30.0</b>	<b>26.8</b>	<b>38.0</b>	<b>25.7</b>	<b>29.6</b>	<b>16.1</b>	<b>19.1</b>		<b>28.9 25.4</b>
<b>GOLD BAR (3)</b>														
First Sample	15.4	33.8	37.9	31.3	18.8	45.4	30.2	41.0	16.1	22.5	35.4	18.8	<b>45.4</b>	
Second Sample	20.9	14.1	44.2	30.2	38.4	39.9	34.0	25.4	67.8	30.7	10.1	46.4	<b>67.8</b>	
Third Sample	15.2	25.4	32.2	56.9	11.1	44.6	32.4	26.1	23.7	19.0	3.9	25.1	<b>56.9</b>	
Fourth Sample	28.7	31.9	16.4	15.5	45.1	9.9	18.2	29.8	26.0	61.0	26.6	19.9	<b>61.0</b>	
Fifth Sample	17.5	88.6	41.5	22.7	30.8	27.3	41.1	55.3	10.1	21.5	20.6	16.3	<b>88.6</b>	
Sixth Sample	-	-	-	-	-	-	-	28.6	-	-	-	-	<b>28.6</b>	
<b>MONTHLY AVERAGE</b>	<b>19.5</b>	<b>38.8</b>	<b>34.4</b>	<b>31.3</b>	<b>28.8</b>	<b>33.4</b>	<b>31.2</b>	<b>34.4</b>	<b>28.7</b>	<b>30.9</b>	<b>19.3</b>	<b>25.3</b>		<b>29.7 25.9</b>
<b>BEVERLY (5)</b>														
First Sample	14.8	39.1	50.3	58.9	21.5	41.6	35.1	46.2	18.3	27.4	57.5	23.4	<b>58.9</b>	
Second Sample	22.5	17.3	66.2	40.0	45.1	42.9	31.9	34.8	58.3	47.0	15.1	46.9	<b>66.2</b>	
Third Sample	17.2	46.5	77.8	55.3	13.5	43.6	42.4	41.7	29.9	46.4	7.9	28.2	<b>77.8</b>	
Fourth Sample	35.3	40.2	20.3	24.0	47.7	12.1	24.9	30.1	33.1	43.9	24.4	29.3	<b>47.7</b>	
Fifth Sample	27.2	128.4	51.2	25.0	50.6	36.3	47.3	68.7	15.4	36.6	26.3	20.0	<b>128.4</b>	
Sixth Sample	-	-	-	-	-	-	-	33.4	-	-	-	-	<b>33.4</b>	
<b>MONTHLY AVERAGE</b>	<b>23.4</b>	<b>54.3</b>	<b>53.2</b>	<b>40.6</b>	<b>35.7</b>	<b>35.3</b>	<b>36.3</b>	<b>42.5</b>	<b>31.0</b>	<b>40.3</b>	<b>26.2</b>	<b>29.6</b>		<b>37.4 33.2</b>
<b>EXCEEDANCES</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>		

**Table 9 Continued.**

**OVERALL THREE STATION AVERAGES - (By Sampling Date)**

<b>THREE STATIONS (DAILY AVERAGE)</b>	<b>JAN</b>	<b>FEB</b>	<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>	<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>MAX.</b>	<b>ANNUAL AVERAGE arithm. geom.</b>
First Sample	14.3	34.8	44.1	38.7	18.7	40.6	30.4	47.6	18.5	21.2	38.1	21.4	<b>47.6</b>	
Second Sample	20.8	18.3	48.0	35.1	45.9	40.8	29.0	30.1	58.3	36.2	10.6	40.1	<b>40.1</b>	
Third Sample	19.2	32.2	50.4	52.0	11.6	43.1	36.8	33.4	23.1	36.1	5.9	23.1	<b>52.0</b>	
Fourth Sample	28.2	43.5	19.6	19.9	41.5	11.8	21.8	27.5	31.7	47.0	26.3	22.7	<b>47.0</b>	
Fifth Sample	25.4	104.9	43.5	23.5	36.7	28.2	39.2	56.5	10.9	27.4	23.5	15.8	<b>104.9</b>	
Sixth Sample	-	-	-	-	-	-	-	31.9	-	-	-	-	<b>31.9</b>	
<b>THREE STATIONS MONTHLY AVERAGE</b>	<b>21.6</b>	<b>46.7</b>	<b>41.1</b>	<b>33.5</b>	<b>30.9</b>	<b>32.9</b>	<b>31.4</b>	<b>38.3</b>	<b>28.5</b>	<b>33.6</b>	<b>20.6</b>	<b>24.7</b>		<b>32.00 28.00</b>

- NOTES:
1. Units:  $\mu\text{g}/\text{m}^3$
  2. Alberta Environmental Protection Guideline:  $100 \mu\text{g}/\text{m}^3$
  3. Samples were taken every six days for a 24 hour period

N.A. - flowchart lost in transit  
 \*41.1 - substitute for a lost filter on March 16/96  
 (second sample in March)

**Table 10 Particulate monitoring results of West Central Airshed Society for 1997.**

**A. Average and maximum concentrations of PM<sub>10</sub> and PM<sub>2.5</sub> (µg m<sup>-3</sup>) in 1997.**

Station	Particle Size	Average	Maximum
Violet Grove	PM <sub>10</sub>	33.1	113.0
Violet Grove	PM <sub>2.5</sub>	5.8	31.0
Tomahawk*	PM <sub>2.5</sub>	9.7	44.9
Hightower Ridge*	PM <sub>2.5</sub>	3.6	10.0

\* Average and maximum concentrations are from May to December 1997 period. Hightower Ridge is a background site.

**B. Average and maximum concentrations of chemical species in PM<sub>10</sub> size particles. Violet Grove, 1997 (micrograms per cubic meter).**

Particulate Species	Average	Maximum
Nitrate	1.28	2.59
Sulphate	1.88	4.40
Ammonium	0.62	2.10
Chloride	0.08	0.28
Sodium	0.15	0.44
Potassium	0.13	0.28
Magnesium	0.12	0.22
Calcium	2.68	6.55

**Table 10            Concluded.**

**C.    Average and maximum concentrations of chemical species in particles less than 2.5 microns in size, 1997 (micrograms per cubic meter).**

<b>Particulate Species</b>		<b>Violet Grove</b>	<b>Tomahawk</b>	<b>Hightower Ridge</b>
Nitrate	Average	0.49	0.57	0.11
	Maximum	1.53	1.41	1.18
Sulphate	Average	1.35	1.14	0.57
	Maximum	3.31	3.44	1.77
Ammonium	Average	0.79	0.69	0.19
	Maximum	1.89	1.89	0.54
Chloride	Average	0.003	0.003	0.008
	Maximum	0.009	0.011	0.173
Sodium	Average	0.020	0.014	0.015
	Maximum	1.060	0.053	0.140
Potassium	Average	0.019	0.018	0.012
	Maximum	0.084	0.067	0.103
Magnesium	Average	0.005	0.003	0.002
	Maximum	0.015	0.007	0.007
Calcium	Average	0.049	0.028	0.011
	Maximum	0.142	0.083	0.034

## 4.0 PHYSICAL AND CHEMICAL CHARACTERISTICS

### 4.1 Urban

The characteristics of inhalable particulate matter in two major cities of Alberta, Edmonton and Calgary, have been summarized and published (Cheng et al., 1998). Tables 11 and 12 show the statistics for the average annual mass loadings of particles. Mean and median concentrations of  $PM_{10}$  are very similar in Edmonton and Calgary. Mean  $PM_{10}$  concentrations in Calgary and Edmonton are 26.3 and 29.1  $\mu\text{g m}^{-3}$ , respectively. Variation of  $PM_{10}$  concentration is greater in Calgary, as shown in the standard deviation and the range. Median  $PM_{10}$  concentrations are 27.0 and 23.0  $\mu\text{g m}^{-3}$ , respectively, in Edmonton and Calgary. Similarly, there is no difference in the statistics of the  $PM_{2.5}$  concentrations between Edmonton and Calgary. Median, mean and standard deviation of concentrations are essentially the same for Edmonton and Calgary measurements. Edmonton has a slightly greater range, having lower minimum and higher maximum values than Calgary. Median  $PM_{2.5}$  mass loading is 9.0  $\mu\text{g m}^{-3}$  in both Edmonton and Calgary. Thus,  $PM_{2.5}$  to  $PM_{10}$  ratio in the two major cities in Alberta is in the range of 0.3 to 0.4. Ratios of  $PM_{2.5}$  to  $PM_{10}$  for different Canadian locations are given in Figure 4. Values for prairie cities are consistently lower than the east or west coast. Figure 5 gives the annual mean 24-hour average  $PM_{10}$  concentrations in both cities for the period from 1985 to 1995.

Coarse particle loadings at Edmonton are generally higher in the spring (March to May); while at Calgary, they are slightly higher in winter (December to February). Both city stations show the  $PM_{2.5}$  loadings are slightly greater in winter. The low mixing height in the wintertime may be the cause for the higher concentrations. The current and proposed particulate standards and objectives are based on the total mass concentrations, primarily because of technological limitations. A full review on the measurement methods to determine compliance with suspended particulate standard has been given by Chow (1995).

The results of the chemical analyses are summarized in Figure 6 (Cheng et al., 1998). The fraction of ammonium represents the concentration of ammonium ion that would be required if all sulphate was represented as ammonium sulphate, and all nitrate as ammonium nitrate. Therefore, it provides an upper limit to the true concentration of the ammonium ion. In general, a higher fraction of soil can be found in the coarse particles than in the fine particles: about 55 to 65% for coarse, and only 7 or 8% for fine. Sulphate is the highest analyzed constituent in fine particles, making up almost 11% in both cities. Because carbonaceous and aqueous species were not analyzed, the fraction of the "other" category in both fine and coarse particles is quite large. The fractions of minerals and sulphate in fine particles measured at Edmonton and Calgary are very similar to those obtained at sites in the central United States (U.S. EPA, 1996).

The seasonal chemical composition of fine particulate matter for Edmonton and Calgary is given in Figure 7. Only dominant components are shown. Although there are subtle differences between the chemical composition of the fine and coarse particles, the chemical profiles of particulate matter at Edmonton and Calgary are very similar, especially for fine particles. Furthermore, except for a few

**Table 11 Average annual particulate matter concentrations in Edmonton for the period 1985 - 1995.**

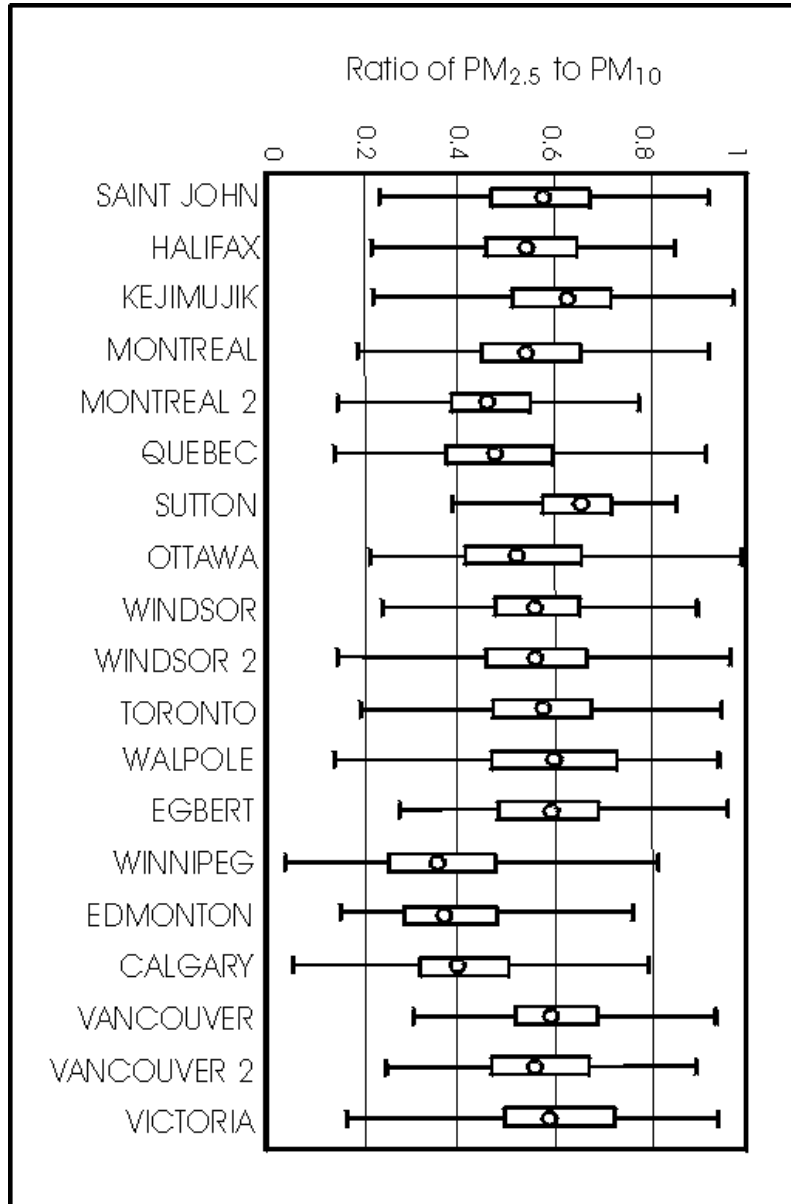
	PM <sub>2.5</sub>			PM <sub>10</sub>		
	Mass	SO <sub>4</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	Mass	SO <sub>4</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>
(µg m <sup>-3</sup> )						
Minimum	0.4	0.01	ND	4.0	0.13	ND
Mean	11.2	1.40	0.49	29.1	1.63	0.68
Median	9.0	1.00	0.2	27.0	1.25	0.39
Standard Deviation	7.6	1.28	0.97	14.2	1.36	0.99
Maximum	56.3	11.14	8.28	86.0	12.57	8.61

ND = Non-detectable

**Table 12 Average annual particulate matter concentrations in Calgary for the period 1985 - 1995.**

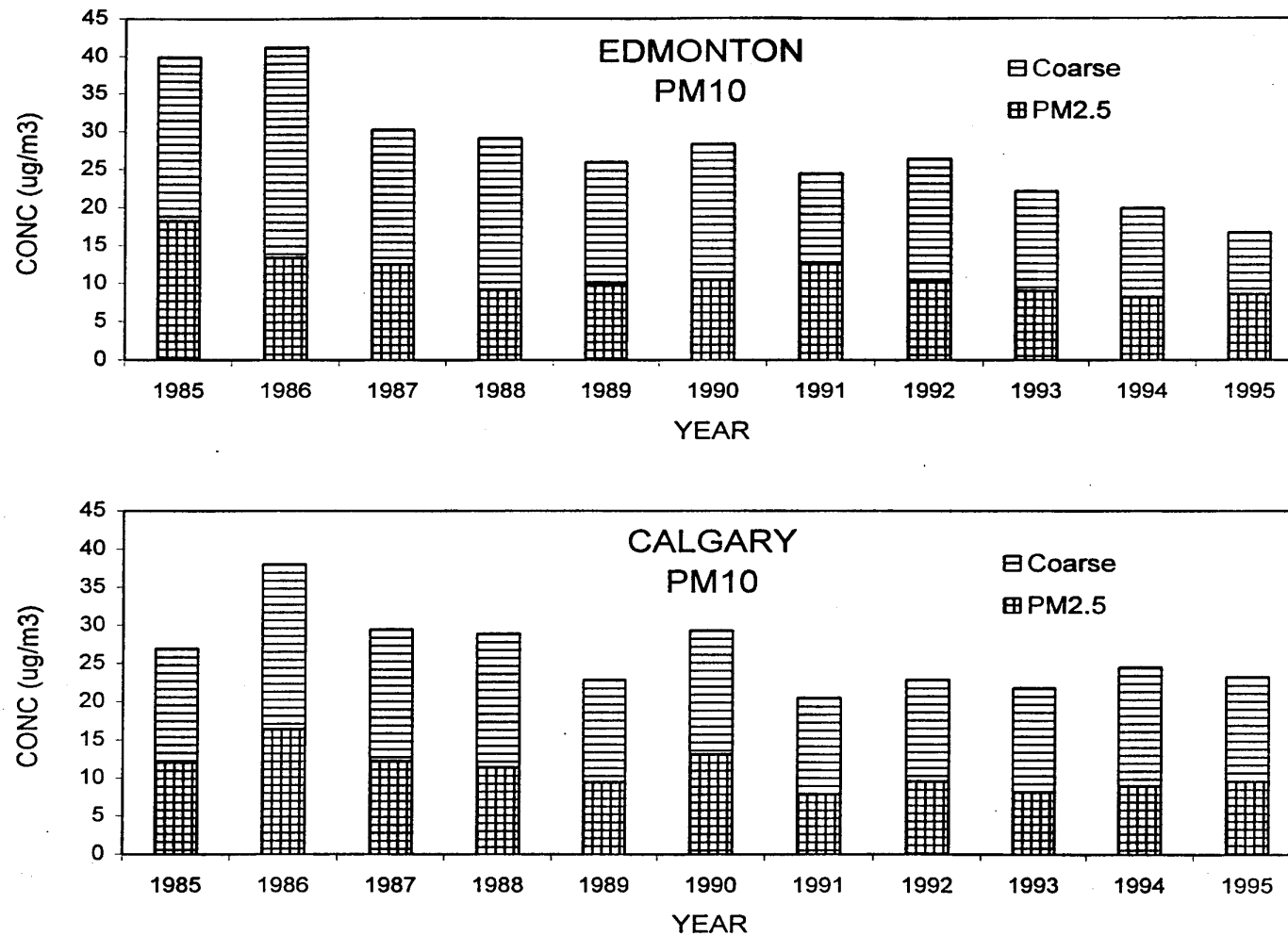
	PM <sub>2.5</sub>			PM <sub>10</sub>		
	Mass	SO <sub>4</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	Mass	SO <sub>4</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>
(µg m <sup>-3</sup> )						
Minimum	2.0	0.1	ND	4.0	0.1	ND
Mean	11.1	1.5	0.5	26.3	1.8	0.7
Median	9.0	1.0	0.2	23.0	1.3	0.4
Standard Deviation	7.7	1.6	1.1	15.2	1.8	1.3
Maximum	52.0	16.2	15.6	114.0	18.9	17.5

ND = Non-detectable

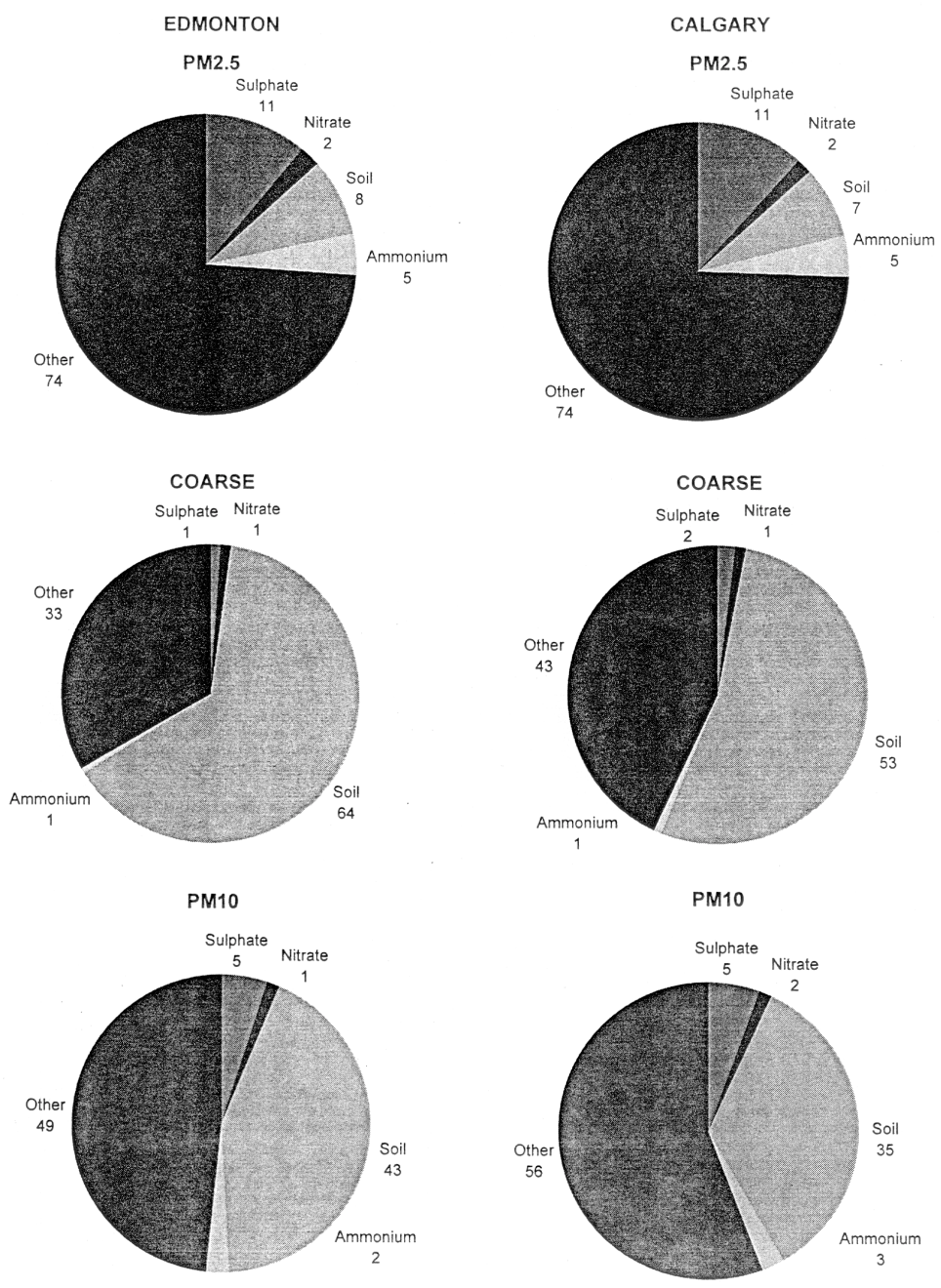


**Figure 4** Distributions of the mass ratio of PM<sub>2.5</sub> to PM<sub>10</sub> at the National Air Pollution Surveillance dichot sites for the period of 1983 to 1993. The box plots indicate the mean ratios and their 5<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup> and 95<sup>th</sup> percentiles (Brook, Dann and Burnett, 1997).

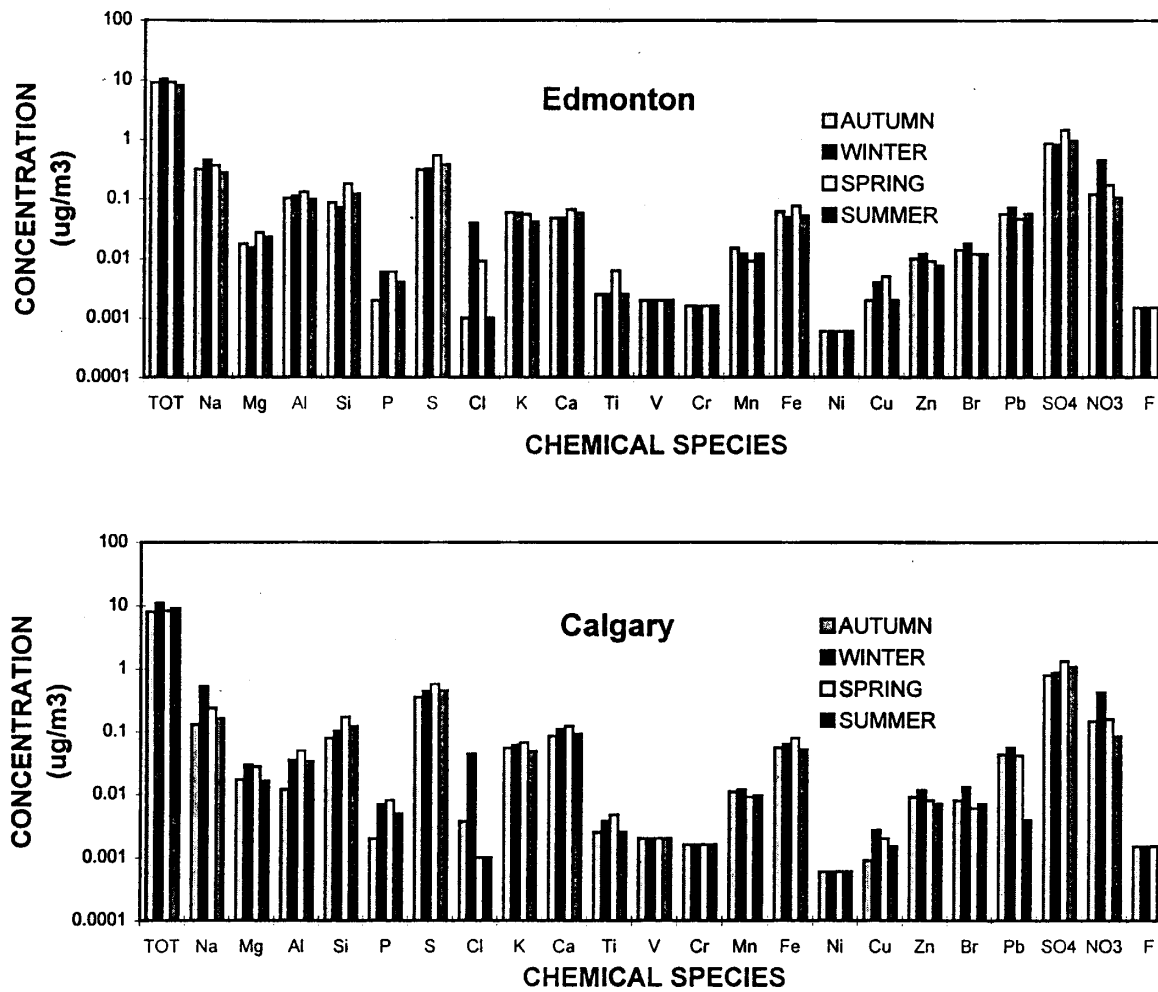




**Figure 5** Annual mean 24-hour average PM<sub>10</sub> concentrations in Edmonton and Calgary for the period of 1985 to 1995. PM<sub>2.5</sub> and the coarse fraction of particulate matter are included.



**Figure 6** Mass apportionment of PM<sub>2.5</sub>, coarse fraction of particulate matter and PM<sub>10</sub> in Edmonton and Calgary for the period of 1985 to 1995.



**Figure 7** Seasonal variation of PM<sub>2.5</sub> chemical composition in Edmonton and Calgary (dominant species only) for the period of 1985 to 1995.

components (e.g., Na, P, Cl and  $\text{NO}_3$ ), seasonal variations within individual chemical components are relatively small when compared with the variations among chemical components. The differences in concentration among Na, Mg and Al, as an example, are much greater than the differences in seasonal concentration for Na, Mg or Al. The results suggest that particulate matter in Edmonton and Calgary may originate essentially from similar dominant sources, despite geographical and industrial differences. In Edmonton and Calgary, an average of about 80% of the particulate sulphur mass is within the fine fraction. Lead and bromine concentration, found mostly within the fine size range (about 70% and 80%, respectively, in both cities), decreased significantly from May 1984 to March 1993 due to the phasing out of lead in gasoline. After the complete ban of leaded fuel consumption in December 1990, concentrations of lead and bromine in particles dropped to less than 3% and 2%, respectively, of the 1984 median values by 1993 at both locations. Inhalable particulate lead and bromine concentrations are less than 0.01 and 0.002  $\mu\text{g m}^{-3}$ , respectively, in Edmonton and Calgary in 1993.

Statistics of the average annual  $\text{SO}_4^-$  and  $\text{NO}_3^-$  composition in inhalable particulate matter for Edmonton and Calgary are shown in Tables 11 and 12. The median and mean concentrations of sulphate and nitrate in both cities are very similar, while the variation and range is slightly higher in Calgary. Calgary has much higher maximum values in sulphate, nitrate and  $\text{PM}_{10}$  concentrations and relatively higher  $\text{NO}_x$  concentration. Median  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$  mass loadings are about 1.0 and 1.25  $\mu\text{g m}^{-3}$  for sulphate, and 0.20 and 0.39  $\mu\text{g m}^{-3}$  for nitrate, respectively in Edmonton and Calgary. Only about 20% of the sulphate mass is in the coarse fraction of the inhalable particulate matter, whereas nitrate is about 50%. It should be noted that the urban air quality in Alberta, including particulate matter, is affected by forest fires (Cheng et al., 1998).

In order to explain the above noted differences in the data for Edmonton and Calgary, the role of sources, meteorology, geography and medium range transport of particulates to cities need to be considered. Sources of particulate matter in both cities include transportation, soil and road dust, wood-burning, forest product manufacturing plants, steel foundries, cement distribution centre, chemical industry, and asphalt roofing manufacturing plants, as well as secondary particles generated by chemical transformation of gases such as  $\text{SO}_2$  and  $\text{NO}_x$ . In addition, Edmonton has gas-fired power plants, petroleum refineries, a cement kiln and coal-fired power plants in its surroundings.

Receptor models use ambient measurements of chemical species to apportion the contributions of various sources. These models assume that the emissions from different sources have characteristic profiles. Using the U.S. Environmental Protection Agency's Source Specification data and the Chemical Mass Balance Model preliminary estimates of dominant local and regional sources of particulate matter and their contributions to Alberta cities have been published recently (Cheng et al., 1998). These authors detected seasonal variations in source contribution, especially for mineral soil and road salt. However, uncertainties were large because no local source profile data and regional background data were available. Current research undertaken in Alberta on source emission profiles and apportionment will provide the needed information for improved estimates (ARC, 1998).

## 4.2 Rural

Rural information on  $PM_{10}$  and  $PM_{2.5}$  from Alberta is very limited. Rural locations without significant sources where monitoring has been done and results have become available at the time of writing this report are given in Table 13. These preliminary results indicate that the background concentrations in Alberta of  $PM_{2.5}$  are low, in the range of 3 to 6  $\mu\text{g m}^{-3}$ , whereas background  $PM_{10}$  concentrations range from 10 to 24  $\mu\text{g m}^{-3}$ . The background ratio of  $PM_{2.5}$  to  $PM_{10}$  is about 0.3. This ratio in aged particles, distant from pollution sources of sulphur dioxide, nitrogen oxides and volatile compounds, can increase considerably. Measurements made so far near significant local sources suggest that local and regional sources can significantly increase  $PM_{2.5}$  and  $PM_{10}$  concentrations.

**Table 13 Monitoring results of PM<sub>10</sub> and PM<sub>2.5</sub> at rural locations in Alberta (micrograms per cubic meter ) during 1993 to 1997.**

<b>Location</b>	<b>Time Period</b>	<b>Total Samples</b>	<b>Mean PM<sub>2.5</sub></b>	<b>Mean PM<sub>10</sub></b>	<b>PM<sub>2.5</sub>/PM<sub>10</sub></b>
Royal Park	1993 to 1995	138	9.14	16.39	0.56
Swan Hills	July 1997	3	2.90	10.40	0.27
Hightower	1997	13	3.6	-	-
Tomahawk	1997	14	9.7	-	-
Violet Grove	1997	23	5.8	33.1	0.18
Caroline/Sundre	July 1997	-	5.00	14.00	0.35
Hinton	Jan. and Feb. 1997	4	4.8	9.0	0.54

## 5.0 DISCUSSION

### 5.1 General

The long-term median concentrations of inhalable particulate matter observed at Edmonton and Calgary are compared with some other continental cities in North America (Table 14). Median concentrations of  $PM_{2.5}$  are  $9 \mu\text{g m}^{-3}$  in both cities, and  $PM_{10}$  are 27 and  $23 \mu\text{g m}^{-3}$ , respectively, in Edmonton and Calgary. In Edmonton, the ratio of median concentrations for  $PM_{2.5}$  and  $PM_{10}$  is 0.33, and in Calgary, 0.39. The  $PM_{2.5}$  concentrations at Edmonton and Calgary are significantly lower than those in eastern North America, but the  $PM_{10}$  concentrations are only slightly lower.  $PM_{10}$  concentrations in Alberta cities lie well within the cross-Canada range of 18 to  $46 \mu\text{g m}^{-3}$  with most sites between 20 to  $30 \mu\text{g m}^{-3}$  (Dann, 1994; Brook et al., 1997). A cross-Canada range of mean  $PM_{2.5}$  concentrations of 8 to  $22 \mu\text{g m}^{-3}$  was determined for the same time period. In the Canadian prairies, mean  $PM_{2.5}$  accounted for less than 36 to 42% of mean  $PM_{10}$ , while in eastern Canada and the province of British Columbia, the fine fraction is about 60% of  $PM_{10}$ . Mean  $PM_{2.5}$  and  $PM_{10}$  concentrations in Winnipeg are 10.3 and  $28.7 \mu\text{g m}^{-3}$ , respectively. The eastern Canada values are very similar to those observed at major cities in central and eastern United States. Natural background  $PM_{2.5}$  and  $PM_{10}$  concentrations for eastern and western United States are estimated to be 1.47 and  $4.47 \mu\text{g m}^{-3}$ , respectively, having an error factor of about 2 (NAPAP, 1990). However, recent observations at Grand Canyon National Park, far remote from any anthropogenic emissions, showed  $PM_{2.5}$  and  $PM_{10}$  concentrations of 4.5 and  $9.4 \mu\text{g m}^{-3}$ , respectively (Malm et al., 1994). Thus, a considerable portion of inhalable particulate matter concentration in the two Alberta cities is likely from regional background. Background concentrations of coarse and fine particles differ with the region, depending upon the natural sources in the region and long-range transport.

In general, inhalable particulate matter in Edmonton and Calgary possess similar physical characteristics, as well as some common chemical attributes. Although contributions from various emission sources are different, the natural emissions, the cold and dry climate, and the low mixing layer, may have greater impacts on the physical properties of airborne particles in Alberta. Regional background concentrations are likely dominant in Alberta and the prairies, where local anthropogenic sources are relatively few in number and small in emissions. Non-urban  $PM_{10}$  concentrations in the northwestern U.S. show low values ranging between 7 to  $14 \mu\text{g m}^{-3}$  and coarse particles account for more than half of the  $PM_{10}$  (U.S. Environmental Protection Agency, 1996).

Organic and elemental carbon are important components in particles emitted from most industrial and non-industrial sources (Chow, 1995). In the ambient concentration data organic and elemental carbon were not analyzed. Additional research, monitoring, as well as a breakdown of the predominant organic chemical species, need to be undertaken to develop proper control strategies.

### 5.2 Proposed National Objectives for Particulate Matter and Alberta Situation

As mentioned earlier, the Working Group on Air Quality Objectives and Guidelines published their report "Particulate Matter ( $PM_{10}$  and  $PM_{2.5}$ ) Science Assessment Document" (WGAQOG, 1996).

**Table 14 Average annual median PM<sub>2.5</sub> and PM<sub>10</sub> concentrations in Edmonton and Calgary for the period of 1985 - 1995 as compared to some other continental sites in North America (micrograms per cubic meter).**

	PM <sub>2.5</sub>	PM <sub>10</sub>	PM <sub>2.5</sub> /PM <sub>10</sub>
Edmonton	9	27	0.33
Calgary	9	23	0.39
Winnipeg <sup>a</sup>	10.3	28.7	0.36
Toronto <sup>a</sup>	16.8	28.1	0.60
Montreal <sup>a</sup>	15.9 - 20.9 <sup>b</sup>	27.8 - 44.6 <sup>b</sup>	0.47 - 0.57
Washington, DC	26.5	34.9	0.76
St. Louis <sup>d</sup>	17.7 - 19.0	27.6 - 31.4	0.61 - 0.64

<sup>a</sup> Brook et al., 1997

<sup>b</sup> Measurements were made at two different sites

<sup>c</sup> Malm et al., 1994

<sup>d</sup> Spengler et al., 1983 and Dockery et al., 1992



This is a science-based document describing the physical and chemical characteristics of PM<sub>10</sub> and PM<sub>2.5</sub>, methods for sampling in the atmosphere, sources to the atmosphere, and ambient levels as well as the effects of PM on vegetation, human health and visibility. It is recommended that two-tier approach be used for setting objectives for particulate matter:

**The Reference Level:** A level above which there are demonstrated effects on human health and/or the environment. It provides a basis for establishing goals for air quality management.

**The Air Quality Objective:** Represents the air quality management goal for the protection of the general public and the environment in Canada. It was a level based upon consideration of scientific, social, economic and technological factors.

The same Working Group published Part 2. Recommended Air Quality Objectives Report in 1997 (WGAQOG, 1997). Options outlined for particulate air quality objectives are given in Table 15. It was recommended that Reference Levels be set at 25 and 15 µg m<sup>-3</sup> for PM<sub>10</sub> and PM<sub>2.5</sub>, respectively. The recommended PM<sub>10</sub> levels is based upon the lowest ambient PM<sub>10</sub> concentration at which a statistically significant relationship can be identified between PM<sub>10</sub> levels and hospital admission rates for respiratory illness (Burnett et al., 1994). Also, science assessment document states that due to lack of quantitative dose-effect information, it is not possible to define a Reference Level. In addition, there is no clear evidence of a “Threshold” level for the positive associations between particulate matter and both daily mortality and hospitalization rates. The lack of evidence of a threshold precludes the identification of a “safe” level.

A recent draft discussion paper outlines key elements of a proposed Canadian strategy on particulates (Environment Canada, 1997). In this discussion paper, two management strategy options were suggested:

1. Interim targets could be set using a **gap management approach**. Under such an approach, every area in Canada presently exceeding the air quality objective would be required to implement a program aimed at reducing the gap between current levels and the air quality objective by the same percentage. Under such a management approach, the future target ambient level would vary at each location across Canada, but the percentage reduction from current levels would be consistent nationally. The timeframe for the interim target to be achieved would also be consistent across Canada. It should be noted that under such a program, all jurisdictions presently exceeding the air quality objectives would be required to immediately implement a program aimed at achieving the long term objective, regardless of how much the current levels exceed the objective.

**Table 15 Options for PM Air Quality Objectives by the National Working Group (WGAQOG, 1997).**

Method of Development	Basis	Form	AQO Options	
			PM <sub>10</sub>	PM <sub>2.5</sub>
			µg/m <sup>3</sup> over 24 hours	
Lowest Observed Adverse Effect Level (LOAEL)	Health based level at which statistically significant adverse effects on human health can be detected	concentration limit	25	15
LOAEL with a margin of safety	Health based level, simulating a NOAEL, equivalent to ambient background	concentration limit	15	10
Median of the 90th percentile of ambient data	Consideration of current Canadian ambient conditions	concentration limit	40	25
Rolling targets with progressive reduction of targets in 5 year intervals	Implementation approach with phased application of a series of increasingly stringent levels culminating with the LOAEL	concentration limit	40 by 2000 35 in 2005 32 in 2010 25 in 2015	25 by 2000 20 in 2005 17.5 in 2010 15 in 2015
Percentage Attainment	Phased attainment of a concentration limit equal to the LOAEL	concentration limit plus attainment target	target = 25 80% attainment by 1998; 90% attainment by 2000; 95% attainment by 2005	target = 15 80% attainment by 1998; 90% attainment by 2000; 95% attainment by 2005
Incremental Risk Analysis	Determination of the health impacts associated with cumulative concentrations in 1 µg/m <sup>3</sup> increments above the LOAEL	concentration limit or cumulative concentration	evaluation tool	evaluation tool

2. Another approach could be to set **national interim target ambient levels**. For example, if the air quality objective is  $20 \mu\text{g m}^{-3}$ , a national target of  $30 \mu\text{g m}^{-3}$  could be set for 2010, with the long term goal remaining at the air quality objective of  $20 \mu\text{g m}^{-3}$ . Using this approach, only areas exceeding  $30 \mu\text{g m}^{-3}$  would be required to implement control programs between now and 2010, but all jurisdictions exceeding the air quality objective would be required to implement control programs aimed at achieving the objective by 2030. This approach may be more consistent with the Canada wide standards concept by providing a common level of protection for all Canadians which could be step-wise reduced over time.

The final outcome of federal-provincial discussions on this subject is not known yet. It is worth noting, however, that at the December 1997, National Stakeholder Consultation Workshop, the Working Group suggested a national ambient 24-hour objective for  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  of 40 and  $20 \mu\text{g m}^{-3}$ , respectively. If Alberta adopts such values, some exceedances are expected (see Tables 4 and 5).

As scientific studies on the effects of ambient particulate matter on human health from Alberta are non-existent, the proposed Reference Levels, based on Canadian and U.S. studies, appear reasonable. The Alberta Oil Sands Community Exposure and Health Effects Assessment study report is the initial step in this direction for obtaining Alberta information (Alberta Health, 1997).

It is known that Alberta's emissions contribute to both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ . Results of preliminary particulate monitoring, undertaken outside cities in Alberta over the last two years (Tables 6, 8 and 10), indicate a large variation in mean and maximum values. Rural and regional background particulate matter information from different Alberta regions is limited. Such information is needed to define the baseline air quality for particulate matter in Alberta. This, in turn, will help in carrying out any future trend analysis on  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ . Using currently available data, such as in Tables 4 and 5, and other annual monitoring reports, analysis of exceedances from the proposed 24-hour objective for  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  should be undertaken. A quality control and quality assurance program for the data collected in the future should be implemented. Industry data on TSP should be analyzed, using correlations developed by Alberta Environmental Protection or from the literature, to estimate  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ . Site specific limitations of such correlations are important to recognize in interpreting these estimates. However, this information will serve as a useful preliminary input to the Alberta objective setting process for particulate matter. Additional continuous monitoring of particulate matter in urban and rural settings should be undertaken to establish a solid baseline data set for Alberta.



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## **7.0 APPENDICES**

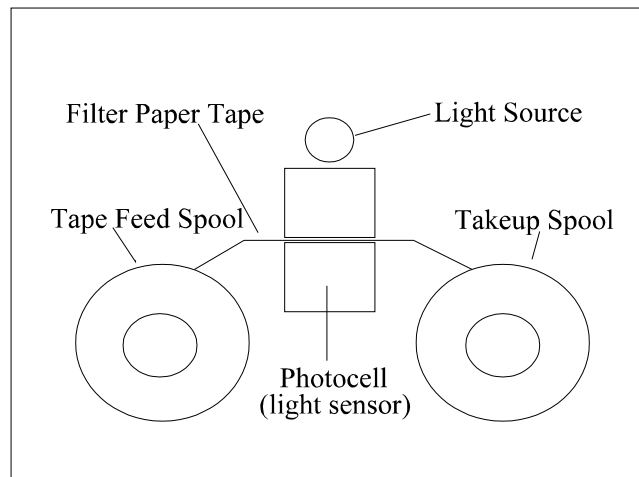
## APPENDIX 1

### A1. Monitoring methods and air quality, and precipitation quality monitoring stations of Alberta Environmental Protection (1997).

#### A1.1 Dust and Smoke expressed as Coefficient of Haze (COH)

The amount of dust and smoke in the atmosphere can be expressed in units of coefficient of haze (COH). Dust and smoke in the atmosphere can originate from various sources, such as roads, wind-blown soil, industrial chimneys, vehicle exhaust, agricultural activities, and open burning.

Tape samplers (**Figure A1.1**) operate on the following principle. Light is transmitted through a clean spot of the filter paper. Air is continually drawn through the section of filter paper tape for one hour. Light is transmitted through the soiled spot on the filter paper and light transmission through the soiled spot is compared to light transmission through the clean spot. Reduction in transmitted light caused by the soiling of the filter paper is reported as the coefficient of haze per 1000 linear feet of air.



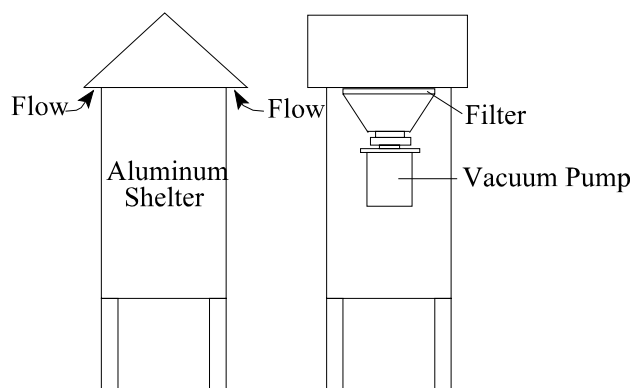
**Figure A1.1 Tape Sampler**

The COH unit is defined as that quantity of particulate matter which produces an optical density (OD) of 0.01 ( $\text{COH} = 0.01\text{OD}$ ). Optical density is defined as the logarithm of the value obtained when the percent transmission of light through a new spot is divided by the percent transmission through a sample spot. For example, a spot which passes 50% of the light compared to the reference area of the tape would have an optical density of 0.301 ( $\text{OD} = \log(100/50) = \log(2) = 0.301$ ) and the sample has a value of 30.1 COH. (Research Appliance Company, *Operating Instructions Manual*). The tape sampler does not account for collection efficiency for the filter paper relative to the size of particles, nor the proportion of particulate mass that does not absorb light (Chow, 1995) The dust and smoke measurement is not a direct measurement of particulate loading but rather the amount of reduction in transmission of light caused by particulate matter expressed as COH per 1000 linear feet of air.

## A1.2 Total Suspended Particulates (TSP)

Total suspended particulates are any solid or liquid particles present in the air that range in size from 0.001 to 500 microns in aerodynamic diameter. Particles less than one micron in diameter are mainly formed through condensation and combustion. Particulates in the range of one to 10 microns generally include soil, process dusts, and combustion products from industries. Particles larger than 10 microns in diameter typically result from mechanical processes such as wind erosion, grinding, spraying and vehicular activity.

TSP are measured for a 24 hour period every sixth days in accordance with to the National Air Pollution Surveillance (NAPS) monitoring schedule. The instrument used to collect TSP is a Hi-Volume Sampler that consists of a vacuum pump and a filter (**Figure A1.2**). A known volume of air is drawn through a pre-weighed filter for 24 hours. At the end of the 24 hour period the filter is reweighed and the mass of the particles collected is determined.



**Figure A1.2 Hi-Volume Sampler**

## A1.3 Particulate Matter less than 10 $\mu$ m (PM<sub>10</sub>)

PM<sub>10</sub> is a component of TSP. PM<sub>10</sub> is defined in regards to the samplers monitoring it. The samplers monitoring PM<sub>10</sub> are designed to have a 50 percent cutpoint ( $D_{50}$ ) of 10  $\mu$ m aerodynamic diameter.

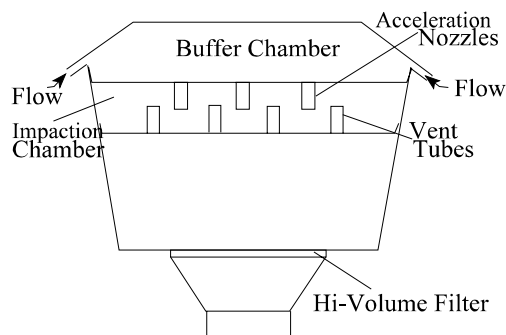
$D_{50}$  is defined as the particle size at which the sampler collects 50 percent of the sample and rejects 50 percent. Particles whose aerodynamic diameters are below the  $D_{50}$  of 10  $\mu$ m are collected at progressively greater than 50 percent efficiency while those particles larger than  $D_{50}$  are collected with progressively less efficiency. Thus, PM<sub>10</sub> samples do contain particles larger than 10  $\mu$ m.

(Dann, 1994)

Particles in this particular range of sizes are becoming more important. At the present time there is concern that these particles are imposing health risks. Particles from 0.1 to 3 microns have the highest degree of penetration and retention in the human respiratory tract. The nose and upper airways efficiently remove particles greater than 3 microns but smaller particles escape these defenses (Rich, 1986). PM<sub>10</sub> particles can cause reactions inside the body, decrease gas exchange capacity and some can adsorb gaseous pollutants and deliver them directly to the lungs.

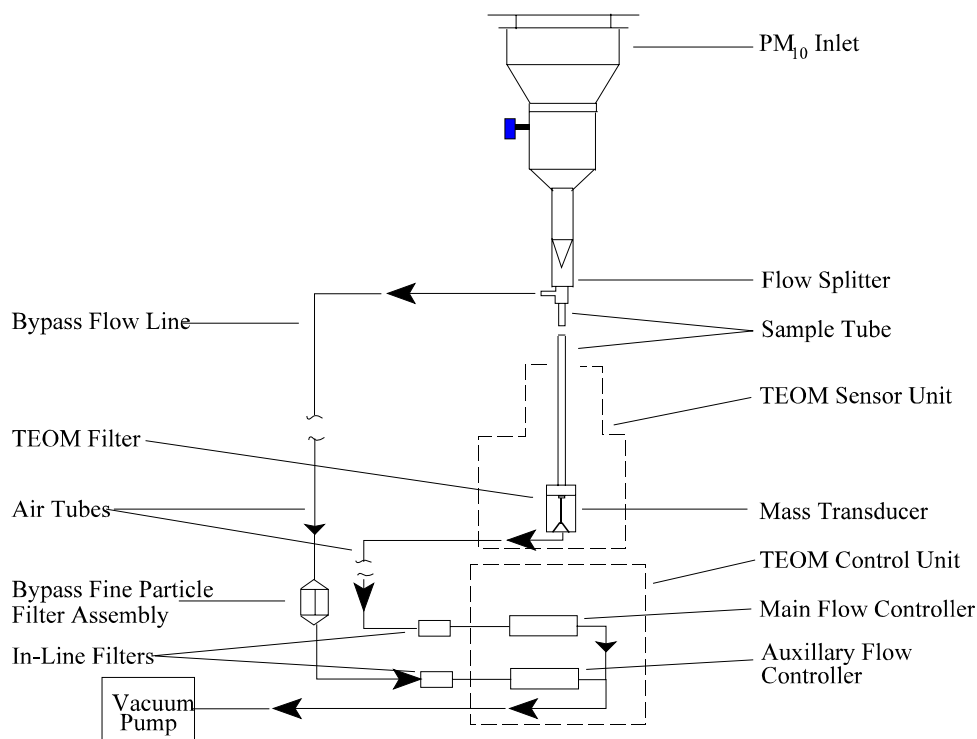
Two different instruments that measure PM<sub>10</sub> are compared in this report. One is a Hi-Volume sampler with a Size Selective Inlet head (SSI) (**Figure A1.3**) and the other is the Tapered Element Oscillating Microbalance (TEOM<sup>®</sup>) (**Figure A1.4**). The two instruments are based on different principles. The SSI reports a daily average measurement and follows the NAPS sampling schedule, whereas the TEOM<sup>®</sup> measures PM<sub>10</sub> continuously and reports as a one hour average. An analysis of the data is necessary to determine if the instruments are obtaining comparable results.

The SSI first removes particles greater than 10µm from the air sample by evacuating the buffer chamber at a rate of 68 m<sup>3</sup>/hr through the acceleration nozzles (**Figure A1.3**). Particles smaller than 10µm pass through the impaction chamber and out through the vent tubes. These particles are then deposited onto a standard high volume filter.



**Figure A1.3 Hi-Volume Size Selective Inlet**

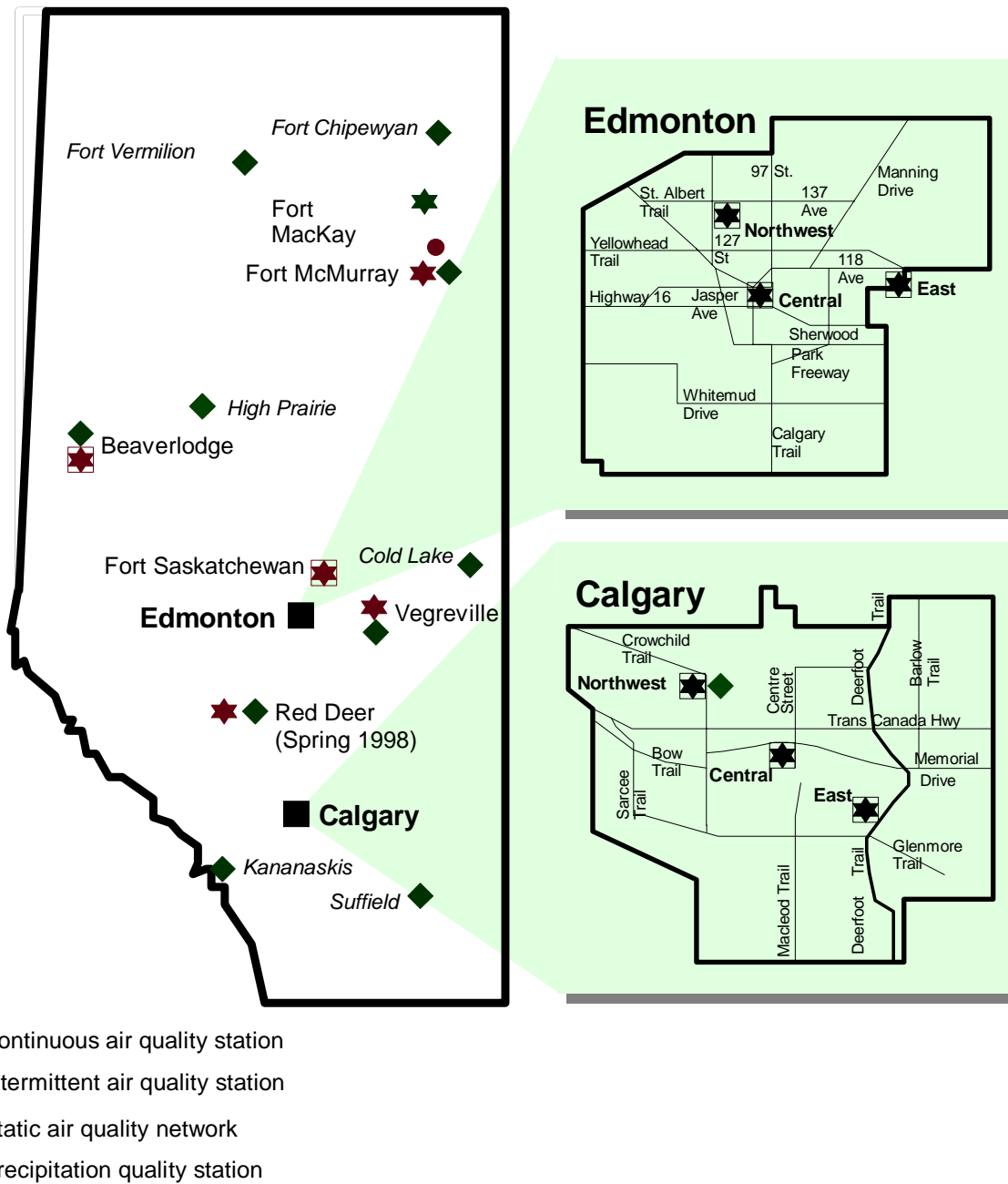
The TEOM<sup>®</sup> draws a sample air stream and permits only particles less than 10µm in diameter to pass through the PM<sub>10</sub> inlet (**Figure A1.4**). The air stream then passes through a filter which is attached to a tapered element in the mass transducer. This tapered element vibrates at its natural frequency, but as particles are deposited onto the filter the frequency changes. This change in frequency is measured every two seconds and the total mass of particles deposited is determined.



**Figure A1.4 TEOM<sup>®</sup>**

**A1.4** All air quality and precipitation quality monitoring stations operated by Alberta Environmental Protection in 1997 are shown in **Figure A1.5**. This monitoring program consisted of:

- ▶ 11 continuous stations that measured hourly concentrations of air chemicals such as carbon monoxide, carbon dioxide, dust and smoke (the coefficient of haze), hydrogen sulphide, oxides of nitrogen (including nitric oxide and nitrogen dioxide), ozone, sulphur dioxide, total hydrocarbons and inhalable particulates;
- ▶ 8 intermittent stations that collected 24-hour measurements of suspended particulates, polycyclic aromatic hydrocarbons, sulphates and nitrates;
- ▶ 2 static networks that monitored monthly loadings of total sulphation and hydrogen sulphide, and
- ▶ 11 precipitation quality stations that collected weekly rain and snow samples which were analyzed for pH and deposition of major cations and anions.



**Figure A1.5 Alberta Environmental Protection air quality and precipitation quality monitoring stations (1997).**

## APPENDIX 2

### A.2 Results of Alberta Environmental Protection particulate monitoring during 1996, taken from Data Report and Detailed Report.

**Table A2.1 Results of particulate monitoring during 1996.**

<b>TOTAL SUSPENDED PARTICULATES (<math>\mu\text{g}/\text{m}^3</math>)</b>					
24 hour guideline = 100 $\mu\text{g}/\text{m}^3$					
<b>Edmonton Central</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	14.6	24.2	29.6	0
	<b>Feb</b>	15.7	122.1	293.0	60
	<b>Mar</b>	27.9	81.0	121.3	40
	<b>Apr</b>	26.8	71.7	114.3	40
	<b>May</b>	42.3	52.8	73.6	0
	<b>Jun</b>	24.6	44.0	50.9	0
	<b>Jul</b>	32.0	48.4	60.5	0
	<b>Aug</b>	35.4	43.4	57.5	0
	<b>Sep</b>	30.1	42.5	58.2	0
	<b>Oct</b>	26.3	43.7	54.9	0
	<b>Nov</b>	14.3	20.2	29.8	0
	<b>Dec</b>	16.7	22.4	28.6	0

<b>Edmonton Northwest</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	7.3	20.3	40.9	0
	<b>Feb</b>	15.4	49.4	149.1	10
	<b>Mar</b>	13.2	41.4	72.2	0
	<b>Apr</b>	16.3	41.7	86.2	0
	<b>May</b>	8.9	23.3	43.8	0
	<b>Jun</b>	8.8	26.0	43.7	0
	<b>Jul</b>	15.5	30.2	47.1	0
	<b>Aug</b>	15.0	34.4	75.1	0
	<b>Sep</b>	0.0	25.0	61.8	0
	<b>Oct</b>	20.7	37.2	61.5	0
	<b>Nov</b>	9.4	23.2	57.0	0
	<b>Dec</b>	17.8	31.0	52.0	0

<b>Edmonton East</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	22.2	31.8	38.7	0
	<b>Feb</b>	26.8	50.1	121.1	20
	<b>Mar</b>	23.2	44.7	72.4	0
	<b>Apr</b>	26.8	60.2	155.6	20
	<b>May</b>	15.2	47.5	71.4	0
	<b>Jun</b>	25.3	55.8	86.6	0
	<b>Jul</b>	20.1	52.4	101.2	20
	<b>Aug</b>	42.6	52.9	66.1	0
	<b>Sep</b>	15.3	41.0	80.0	0
	<b>Oct</b>	29.4	56.1	87.7	0
	<b>Nov</b>	8.1	36.1	65.4	0
	<b>Dec</b>	16.8	42.6	68.0	0

**Table A2.1 Continued.**

Year	Average Annual Concentration		
	Edmonton Central	Edmonton Northwest	Edmonton East
1980	98.2	81.7	70.2
1981	98.1	62.8	64.2
1982	69.5	49.2	59.3
1983	62.1	53.5	47.3
1984	71.7	48.2	47.3
1985	51.7	38.6	43.2
1986	83.9	43.5	50.1
1987	72.7	45.5	49.9
1988	63.3	39.6	51.6
1989	55.4	42.6	46.0
1990	63.2	47.3	52.1
1991	50.2	40.0	41.3
1992	58.1	42.3	49.8
1993	59.0	47.0	63.7
1994	53.9	44.5	55.3
1995	46.4	40.4	43.8
1996	51.2	32.0	47.9



**Table A2.1 Continued.**

<b>TOTAL SUSPENDED PARTICULATES (<math>\mu\text{g}/\text{m}^3</math>)</b>					
24 hour guideline = 100 $\mu\text{g}/\text{m}^3$					
<b>Calgary Central</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	15.4	44.7	86.8	0
	<b>Feb</b>	26.5	47.5	72.5	0
	<b>Mar</b>	21.9	42.3	88.5	0
	<b>Apr</b>	28.6	78.5	135.7	40
	<b>May</b>	24.0	49.2	82.9	0
	<b>Jun</b>	26.0	41.7	61.5	0
	<b>Jul</b>	19.9	51.8	69.6	0
	<b>Aug</b>	32.4	48.4	76.4	0
	<b>Sep</b>	13.4	42.1	100.2	20
	<b>Oct</b>	26.0	46.8	67.9	0
	<b>Nov</b>	18.2	32.9	54.4	0
	<b>Dec</b>	22.1	44.3	96.8	0

<b>Calgary Northwest</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	11.7	21.5	55.4	0
	<b>Feb</b>	19.6	22.8	27.0	10
	<b>Mar</b>	9.5	27.5	46.6	0
	<b>Apr</b>	28.1	43.0	59.9	0
	<b>May</b>	17.0	40.3	81.4	0
	<b>Jun</b>	18.4	30.6	51.4	0
	<b>Jul</b>	29.0	35.0	40.8	0
	<b>Aug</b>	26.0	42.6	66.5	0
	<b>Sep</b>	8.4	26.7	77.6	0
	<b>Oct</b>	14.8	27.1	33.2	0
	<b>Nov</b>	13.7	22.2	26.5	0
	<b>Dec</b>	14.9	18.9	28.7	0

<b>Calgary East</b>		<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>
<b>1996</b>	<b>Jan</b>	54.1	95.4	191.7	20
	<b>Feb</b>	44.1	77.6	129.9	25
	<b>Mar</b>	40.5	69.5	106.2	20
	<b>Apr</b>	27.6	102.1	190.8	40
	<b>May</b>	65.2	92.5	113.7	40
	<b>Jun</b>	40.4	96.6	147.6	60
	<b>Jul</b>	52.2	87.3	134.7	40
	<b>Aug</b>	38.9	84.5	123.5	33
	<b>Sep</b>	36.3	87.4	244.7	20
	<b>Oct</b>	43.0	88.0	124.6	40
	<b>Nov</b>	19.0	65.8	100.8	20
	<b>Dec</b>	24.1	52.2	73.6	0

**Table A2.1 Continued.**

Year	Average Annual Concentration		
	Calgary Central	Calgary Northwest	Calgry East
1980	165.0	70.4	150.0
1981	147.0	69.3	133.0
1982	117.0	48.7	98.1
1983	80.7	39.4	81.7
1984	72.1	40.6	70.0
1985	59.1	38.2	62.5
1986	79.5	49.5	83.4
1987	85.3	47.9	75.6
1988	76.8	38.7	71.1
1989	62.1	34.8	68.2
1990	62.4	41.2	73.9
1991	57.3	36.9	74.2
1992	48.5	36.6	70.7
1993	54.9	35.2	81.4
1994	55.5	33.9	80.7
1995	51.3	29.0	77.3
1996	47.5	30.2	83.4

**Table A2.1 Concluded.**

<b>TOTAL SUSPENDED PARTICULATES (<math>\mu\text{g}/\text{m}^3</math>)</b>					
24 hour guideline = 100 $\mu\text{g}/\text{m}^3$					
<b>Fort Saskatchewan</b>	<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>	
<b>1996</b>	<b>Jan</b>	0.0	11.7	28.1	0
	<b>Feb</b>	11.9	45.8	114.7	20
	<b>Mar</b>	13.3	33.8	72.8	0
	<b>Apr</b>	8.6	18.8	31.2	0
	<b>May</b>	9.8	18.7	25.7	0
	<b>Jun</b>	5.7	16.9	21.8	0
	<b>Jul</b>	9.1	18.2	24.6	0
	<b>Aug</b>	13.8	21.2	32.0	0
	<b>Sep</b>	8.2	18.7	41.9	0
	<b>Oct</b>	13.3	19.9	27.7	0
	<b>Nov</b>	5.9	16.8	27.8	0
	<b>Dec</b>	11.0	20.2	40.2	0

<b>Royal Park</b>	<b>MIN</b>	<b>MEAN</b>	<b>PEAK</b>	<b>% of Exceedances</b>	
<b>1996</b>	<b>Jan</b>	0.4	4.3	8.0	0
	<b>Feb</b>	1.5	11.6	19.1	0
	<b>Mar</b>	9.8	19.6	42.3	0
	<b>Apr</b>	15.4	20.5	25.1	0
	<b>May</b>	11.9	19.4	33.4	0
	<b>Jun</b>	3.7	27.7	66.9	0
	<b>Jul</b>	9.9	19.1	25.3	0
	<b>Aug</b>	10.7	28.6	53.8	0
	<b>Sep</b>	4.4	21.8	60.3	0
	<b>Oct</b>	14.6	28.0	47.0	0
	<b>Nov</b>	3.3	8.0	13.5	0
	<b>Dec</b>	7.6	10.8	18.8	0

<b>Average Annual Concentration</b>			
<b>Year</b>	<b>Ellerslie</b>	<b>Fort Saskatchewan</b>	<b>Royal Park</b>
1982	*	35.3	*
1983	*	34.4	*
1984	*	41.2	*
1985	14.3	30.7	*
1986	24.7	36.3	*
1987	28.5	42.6	*
1988	27.1	33.9	*
1989	20.8	28.5 a	*
1990	22.0	30.6	*
1991	26.2	26.3	*
1992	*	28.1	*
1993	*	36.5	29.2
1994	*	28.3	24.6
1995	*	23.8	19.9
1996	*	21.8	19.1

\* - not available

a - >50 to <75% operational and may not be representative

## **A2.2 Inhalable Particulates (PM<sub>10</sub>)**

### **A2.2.1 Characteristics**

Inhalable particulates or PM<sub>10</sub>, refers to particles that have an aerodynamic diameter of less than 10 micrometres (µm) and are suspended in the air for an indefinite period of time. In general, particles smaller than 1 µm in diameter exist in the atmosphere primarily as by-products of condensation and combustion. Inhalable particulates between 1 and 10 µm in diameter usually include soil, process dusts, and combustion products from industries. Particles larger than 10 µm in diameter result from mechanical processes such as wind erosion, grinding, spraying and vehicular activity.

Since particles enter the body through the respiratory system, most of their immediate effects are on this system. The factor which determines the depth of penetration into the respiratory system is the particle size. Larger particles tend to be deposited in the upper respiratory tract, such as the nose and throat, while smaller particles travel deeper into the lungs. The toxicity of the particles, however, varies with the chemical composition. Particles that can be inhaled are typically less than 10 µm in diameter.

Inhalable particles may result from a variety of natural and anthropogenic sources. These sources include vehicle exhaust emissions, soil, road dust, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces), and industrial emission sources.

### **A2.2.2 Method of Monitoring**

Inhalable particulates are monitored on a continuous basis using the Tapered Element Oscillating Microbalance (TEOM). The TEOM draws an air sample through an inlet stream that aerodynamically separates particles of a specified diameter (e.g. 10 µm). The air sample then passes through a filter that is attached to a tapered element in the mass transducer. This tapered element vibrates at its natural frequency. As particles are deposited onto the filter the oscillating frequency changes in proportion to the amount of mass deposited.

### **A2.2.3 Guidelines**

At the present time, Alberta does not have a guideline for inhalable particulates. However, guidelines for particles less than 10 µm (PM<sub>10</sub>) and less than 2.5 (PM<sub>2.5</sub>) µm in diameter are currently being developed at the national level.

### **A2.2.4 Results**

In 1996, inhalable particulates were monitored continuously at the Edmonton Northwest and Calgary Central monitoring stations. Annual average PM<sub>10</sub> concentrations were 15.9 and 13.1 µg/m<sup>3</sup> at the Edmonton Northwest and Calgary Central stations, respectively. Higher PM<sub>10</sub> values at the Edmonton Northwest station were due to more vehicle traffic in the vicinity of the station (e.g. 127 Street, 132 Ave., 137 Ave. and Yellowhead Trail). The frequency distribution of inhalable particulate data at these stations is presented in Figure A2.1.

A diurnal variation in PM<sub>10</sub> concentrations was evident at the Edmonton Northwest and Calgary Central stations. Values tended to be higher during and after the morning and afternoon rush hours.

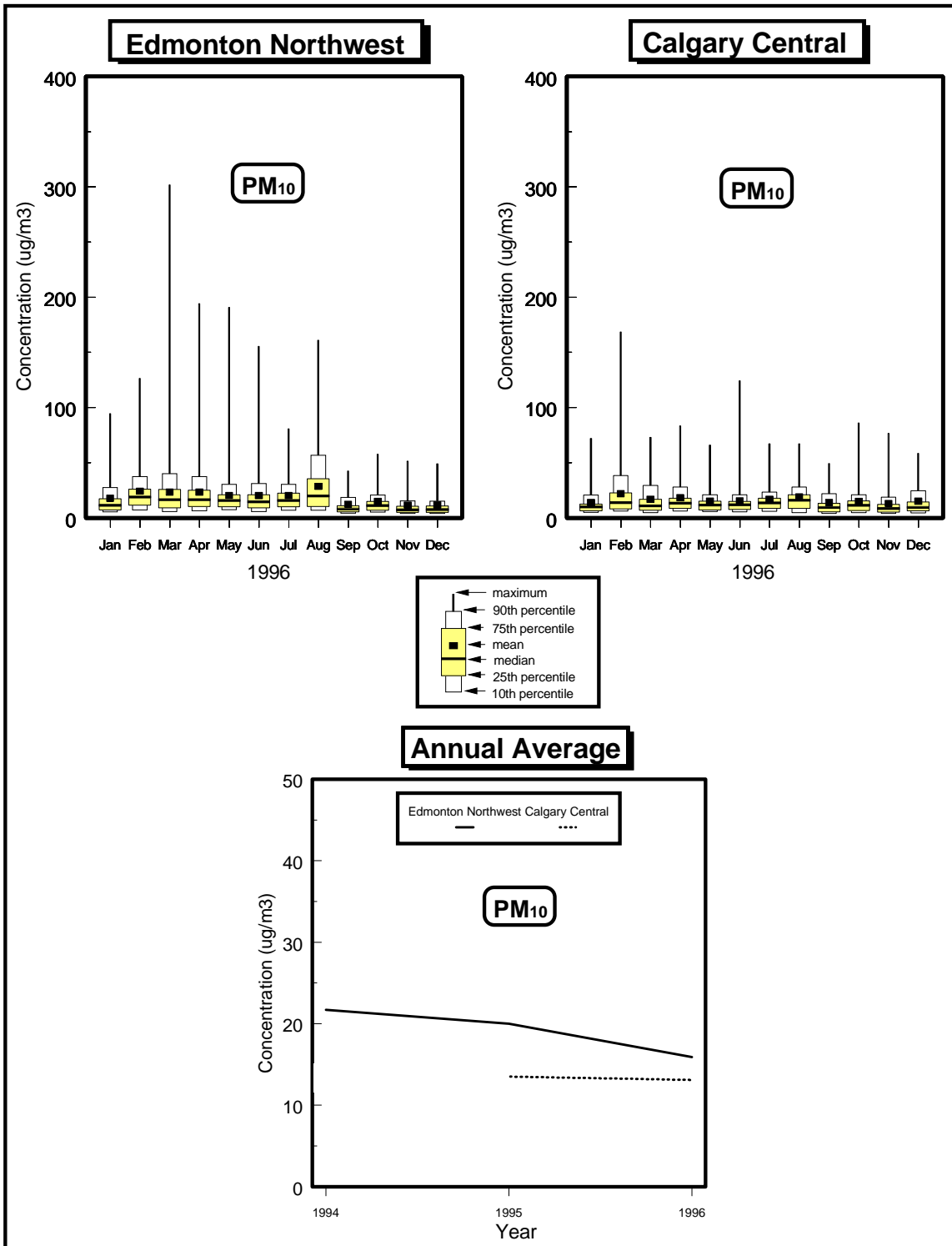
This diurnal trend is especially noticeable in the fall, winter and spring seasons. Higher concentrations at these times can be attributed directly to vehicle exhaust emissions as well as traffic movement.

### ***Edmonton***

The maximum 1-hour average PM<sub>10</sub> concentration at the Edmonton Northwest monitoring station of 302 µg/m<sup>3</sup> was measured in March. Higher PM<sub>10</sub> concentrations were generally recorded in the spring and summer. Higher values in the spring months were likely related to residual sand and dust from winter road sanding. Higher PM<sub>10</sub> values in the late summer and fall months were likely due to vehicle exhaust emissions from nearby major traffic arteries (e.g. 127 Street, 132 Ave., 137 Ave. and Yellowhead Trail).

### ***Calgary***

The maximum hourly average PM<sub>10</sub> concentration (169 µg/m<sup>3</sup>) and the maximum monthly average PM<sub>10</sub> concentration (18.9 µg/m<sup>3</sup>) were recorded in February at the Calgary Central monitoring station. Higher PM<sub>10</sub> concentrations in the winter were likely caused by stable weather conditions which inhibit dispersion of vehicle exhaust emissions. PM<sub>10</sub> concentrations were generally lower in downtown Calgary than at the Edmonton Northwest station because of less vehicle traffic in the vicinity of the monitoring station.



**Figure A2-1 Frequency distribution of PM10 concentrations at Edmonton and Calgary.**